Spring 1977

# VARIETAL RESPONSE OF MAIZE (ZEA MAYS L) TO TEMPERATURES, PLANTING DATES, AND LOCATIONS

SUK SOON LEE

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LEE, Suk Soon, 1943-
VARIETAL RESPONSE OF MAIZE (ZEA MAYS L.)
TO TEMPERATURES, PLANTING DATES,
AND LOCATIONS.

University of New Hampshire,
Ph.D., 1977
Agronomy

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# VARIETAL RESPONSE OF MAIZE (*ZEA MAYS* L.) TO TEMPERATURES, PLANTING DATES, AND LOCATIONS

by

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A THESIS

Submitted to the University of New Hampshire
In Partial Fulfillment of
The Requirement for the Degree of

Doctor of Philosophy
Graduate School
Department of Plant Science

May, 1977

This thesis has been examined and approved.

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Date April 29, 1977

ACKNOWLEDGEMENTS

The author wishes to thank the following persons:

Dr. George O. Estes, major advisor, for his suggestions, guidance, and encouragement during the course of this investigation and in the preparation of the thesis.

Drs. Douglas G. Routley, David W. Koch, Russell S. Kinerson, Thomas Wight, Richard W. Schreiber, and James R. Mitchell for their advice and constructive suggestions.

Dr. Harry A. Keener, Dean of the College of Life Science and Agriculture for financial support.

The members of the faculty and staff of the Department of Plant Science, University of New Hampshire for their assistance.

My wife and two children for their love and understanding.

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# ABSTRACT

## VARIETAL RESPONSE OF MAIZE (ZEA MAYS L.) TO TEMPERATURES, PLANTING DATES, AND LOCATIONS

by

SUK SOON LEE

The performance of silage corn hybrids of varying GDD requirement was tested at different greenhouse temperatures, different planting dates, plant populations, and locations in New Hampshire (N.H.).

In the greenhouse, emergence of 9 hybrids and physiological characteristics of two hybrids were tested at day/night temperatures of 15/10, 20/15, and 26/21 C during 1976-1977. In the field, to determine the optimum planting date, three corn hybrids were tested at four planting dates, April 21, May 5, May 19, and June 2, and at two plant populations, 62,700 and 79,700 seeds/ha, in 1976 at the University of New Hampshire Agronomy Research Farm, Madbury, N.H.

Evaluation of hybrids for tolerance to low temperatures included 20 hybrids planted on the April 21 (early) and May 19 (normal) in 1976 at the University of New Hampshire Agronomy Research Farm, Madbury, N.H. Nine hybrids were also tested at four locations from northern to southern N.H. using recommended planting dates, plant populations, and fertilization at each location in 1976.

Emergence data from the field did not compare with the greenhouse results. In the greenhouse, the percent emergence of most hybrids was low at day/night temperatures of 15/10 C and differences in percent emergence occurred among hybrids. In the field, where soil temperatures averaged 10.3 during the emergence period of the earliest planting, no differences in percent stand occurred among hybrids or between planting dates.

Significant changes occurred in the chloroplast ultrastructure of a late hybrid, Agway 590x, when grown at day/night temperatures of 15/10 C compared to 20/15 C; no such changes were observed in chloroplasts from the early hybrid, Cornell 110, grown at either 15/10 or 20/15 C. Seedling growth of Cornell 110 in the greenhouse and field was superior to Agway 590x at suboptimal temperatures but the final yield was not correlated with seedling growth. Photosynthetic activity of seedlings in the field was not significantly different among 20 corn hybrids nor was it related to the dry matter accumulation.

The earliest safe date for planting corn is 7-10 days before the average last frost date. Early planting of the same hybrids resulted in a higher ear yield, ear-to-total dry matter (TDM) ratio, and percent dry matter (% DM) although TDM was not changed.

A differential yield response of hybrids was observed in different locations. In northern areas, TDM was not related to maturity of hybrids but ear yield decreased with delayed maturity of hybrids. In contrast, in central and southern areas, TDM yield increased with delayed maturity of hybrids but ear yield was not related to the maturity of hybrids. Ear-to-TDM ratio and % DM decreased with delayed maturity of hybrids at all locations.

A regression plot of 20 corn hybrids and 2 planting dates showed that a total of 583 C growing degree days was required between silking to harvest to achieve the optimum 33% DM in silage, and a total of 11.5 C was required to increase % DM by one unit.

At the silking stage leaf area index (LAI) of plants from May 19 planting was higher than either earlier or later planting. LAI increased with delayed maturity of hybrids.

# INTRODUCTION

Corn silage is the most productive and complete single feed for cattle even though the practice of feeding all-corn silage on a year-round basis has not been common (Choppock, 1969). From 1960 to 1974 the production of corn silage increased by 76.8% in the northeastern U.S. and by 69.6% in the USA. This rapid increase was primarily due to the higher yield potential of silage corn and the development of efficient harvesting and handling equipment (Hoglund, 1975). In New Hampshire, the average yield of corn silage from 1970 to 1975 was about 35.6 metric tons/ha (10.7 metric tons/ha of dry matter) assuming 70% water content. Such yields are substantially higher than those of other forage crops (5.6 metric tons/ha for alfalfa and alfalfa mixture hay and 3.9 metric tons/ha for other hay) (USDA, 1973 and 1975). During the above 5 year period, the silage corn production in New Hampshire increased by approximately 20% principally due to an increase in acreage rather than yield per unit area. Because of the high cost of land and machinery, yield increases from the use of improved corn hybrids and cultural practices are the major avenues for further improvement in corn silage procuction.

Generally, the longer season corn hybrids produce the higher yield. However, relatively short-season corn hybrids are grown in New Hampshire because of its limited growing season. Development of adaptable hybrids to low temperatures and the use of effective fungicides for seed treatment make early planting of corn economically feasible. Earlier planting allows corn plants to reach their grain formation period under the conditions of longer day length and higher temperatures as well as to avoid late summer drought during the tasseling period. Specific planting dates and the physiological performance of silage corn hybrids in northern areas are not well understood. Data from the Corn Belt states are not totally relevant since silage corn hybrids may perform differently from grain corn hybrids since different parts of the plants are utilized. In addition, significant interactions between hybrids and climatic conditions other than those for which they were developed.

In this study, the field performance of 20 silage corn hybrids was evaluated in different locations, at different planting dates, and at different plant populations under New Hampshire climatic conditions. In the greenhouse, temperature responses of corn hybrids were tested in terms of percent emergence, ultrastructure of chloroplasts, chlorophyll content, photosynthesis, and dry matter accumulation.

# REVIEW OF LITERATURE

## Growth and Yield Forming Processes in Silage Corn

The growing period of corn from planting to maturity can be divided into three stages: planting to emergence, emergence to silking, and silking to maturity. The period from planting to emergence varies little among hybrids but is temperature dependent. The growing degree day (GDD) requirement from planting to emergence is about 55 C regardless of whether these heat units are accumulated in a few days or over a three week period (Aldrich et al., 1975). However, Lindstrom et al. (1976) found that in wheat the reciprocal of days from planting to emergence was linearly proportional to the reciprocal of the absolute mean soil temperature during the period from planting to emergence.

Several workers have reported that days from emergence to silking vary depending on the specific hybrids, environmental conditions (Gilmore and Rogers, 1958; Cross and Zuber, 1972), and soil nutrient conditions (Peaslee et al., 1971). However, the GDD accumulated from planting or emergence to silking remained relatively constant for a given hybrid regardless of planting date or year when GDD was calculated from the following equation on a daily basis (Gilmore and Rogers, 1958):

$$\text{GDD (C)} = \Sigma\ ((\text{Max Temp} + \text{Min Temp})/2 - 10).$$

Ten degrees centigrade was substituted for the minimum temperature when it fell below 10 C, and 30 C was substituted for the maximum temperature if it was above 30 C (Gilmore and Rogers, 1958). Cross and Zuber (1972) found that subtraction of excessively high temperatures (>30 C) from the equation to account for high temperature stress gave a better estimation of silking date in Missouri where the maximum temperature is frequently higher than 30 C. This period from planting to silking (relative maturity) is closely related to the vegetative growth of hybrids: early hybrids have low vegetative growth and the late hybrids have higher vegetative growth during this growth stage (Hanway and Russell, 1969).

The stage from silking to maturity is also affected by hybrid characteristics and environmental conditions. Hanway and Russell (1969) observed that the rapid dry matter accumulation in the grain began at about 12 days after silking in 11 corn hybrids and the rate of dry matter accumulation was similar for all hybrids, years, and plant populations with an average accumulation of 173 kg/ha/day. However, the length of time during which dry matter accumulated in the grain at a rapid rate varied from 43 to 60 days depending on hybrid and year. This difference in time period closely paralleled differences in grain yield.

Eik and Hanway (1966) found that grain yield was determined by "LAI days"; integrals of LAI from silking to 45 days after silking. Ragland et al. (1965) found that growth rate of the ear (kg/day/plant) was similar when silking occurred between July 26 and Sept. 16 in Kentucky. Duncan et al. (1965) found the growth rate of corn kernels to be positively related to the average air temperature in Kentucky for all grain growing stages.

Hillson and Penny (1965) found that the earliest hybrid in terms of silking date required the most time from silking to maturity; the latest hybrid to silk required the shortest time from silking to maturity. However, other researchers have shown that days from silking to maturity was 50-52 days (Shaw and Thom, 1951) and 60 days (Hallauer and Russell, 1962) regardless of the year or hybrid in Iowa. The GDD accumulated during this growing period differs depending on hybrid, location, and year (Mederski et al., 1973). The above disagreement in characterizing the silking to maturity period in corn may be associated with the differential response of the hybrids to different environments or different criteria for determining maturity.

Theoretically, physiological maturity is the time when dry matter accumulation in the grain reaches its peak. From a practical standpoint, it is difficult to determine this stage without a successive sampling of a large number of plants. Rench and Shaw (1971) found that peak dry matter accumulation in the grain coincided with black layer formation in the kernel while Daynard (1972) found abnormal black layer formation under cool temperature conditions. Moisture content in the grain has been used as an index of maturity but it varied depending on hybrid and year (Hallauer and Russell, 1962; Shaw and Thom, 1951).

Optimum maturity for corn silage is earlier than for corn grain and occurs at about 80% of the final grain yield, 30-35% dry matter (DM) or the late dough stage (Daynard et al., 1974; Buck et al., 1969). As the corn matured, the % DM increased until the late dough stage and then leveled off, and leaf yield decreased continuously from silking to maturity (Cummins and Dobson, 1973). As a whole, the total dry matter (TDM) yield of corn is highest when plants are harvested at 33% DM; a late harvest results in yield reduction due to field losses (Caldwell and Perry, 1971; Byers and Ormiston, 1964). Total digestible nutrient (TDN) of corn ears is higher than that of stalks or leaves; TDN for ears ranged from 70-80%, for stalks 45-54%, and for leaves 52-64% (Cummins and Dobson, 1973). However, whole plant TDN was essentially constant between 24-44% DM in the whole plant. This consistency of whole plant TDN resulted from compensatory changes in yield components (ear, stalk, and leaf) and their digestibility. A decrease in TDN of stover and husks with delayed harvest was compensated by an increase in the proportion of grain (Daynard and Hunter, 1975; Daynard et al., 1974; Buck et al., 1969).

Maturity of silage corn as measured by % DM affects its quality as a dairy feed. Milk production increased as the % DM of silage increased from 25.5 to 33.3% due to increased dry matter intake by the cattle (Huber et al., 1965). Silage with less than 30% DM may cause a seepage loss and undesirable butyric acid formentation due to lack of readily available carbohybrates. This problem may be improved by adding high-carbohydrate feed materials such as cereal grains or molasses (Noller, 1973). In contrast, when silage is excessively dry (55-63% DM), TDN levels and production of desirable lactic and acetic acids as fermentation products may be low. Losses of dry matter and molding of silage may also occur due to improper packing and slow decrease in pH of dry silage (Morrison, 1973). Although TDN intake of late-harvested silage with 51.9% DM was higher than that of normal silage with 31% DM, fat-corrected milk production was the same between the silages probably due to lower TDN of the late-harvested silage (Marx, 1969). Use of an air tight silo and fine chopping of silage may improve the quality of excessively dry silage, but yield losses are inevitable (Byers and Ormiston, 1964; Gordon et al., 1968).

Coppock (1969) indicated that with increasing herd size, limited land resources, and greater emphasis on mechanization, the trend to increased reliance on corn silage is expected to continue. While low in crude protein, Ca, and P for growing calves, there are no specific nutrient problems associated with feeding all-corn silage to dairy cattle although this is not a common practice on a year-round basis. Because of the increasing importance of corn silage as a dairy feed, higher yields and good quality are very important. Quality of silage is largely determined by the maturity of the corn plant, which is significantly affected by choice of hybrid and its planting date. Thus, knowledge about the hybrid x planting date interaction is fundamental to the improvement of yields and quality of corn silage.

## Planting Date

Corn is adapted to a wide variety of climates and therefore the planting date depends largely on temperature. In the past, corn was usually planted 10-14 days after the last frost date due to the infection of corn by soil-borne diseases, mainly *Pythium* spp., under cool soil temperature conditions (Leonard and Martin, 1963). Breeding new hybrids tolerant to these diseases and the use of effective fungicides now make early planting feasible (Aldrich et al., 1975).

When corn was planted early, slow emergence and growth occurred due to low temperatures, but percent emergence remained high if seeds were planted at a soil depth less than 7.6 cm (Alessi and Power, 1971; Cal and Obendorf, 1972). The foliage of early-planted corn may be damaged by the late spring frost, but since the growing point of seedlings is located under the ground and the minimum soil temperature is higher than the minimum air temperature, rapid recovery is common (Aldrich et al., 1975).

In Iowa, the highest grain yield was obtained in an April 30 planting and grain yield decreased 103 kg/ha/day as planting date was delayed beyond this time (Pendleton and Egli, 1969). However, when planted earlier than April 30, no extra yield increase occurred even though higher temperatures and a longer day length occurred during the grain formation period compared to April 30 planting. Lowered yield from extremely early planting was considered to be largely due to a smaller LAI.

In Minnesota, Hicks et al. ( 1976) observed a higher grain yield in an early May planting compared to a late May planting. This higher grain yield of the early planting probably resulted from improved kernel weight due to higher temperatures during the grain formation period compared to the late planting (Ragland et al., 1966; Benoit et al., 1965).

## Yield Potential of Hybrids

Differences in the yield of dry matter from silage corn hybrids varying in maturity are not well documented. No significant yield differences occurred among the 20 hybrids in a 10-year experiment in northern New York (Rutger, 1969), among 12 hybrids grown in southern New Hampshire (Bruetsch and Estes, 1976), or between two hybrids in Georgia (Cummins and Dobson, 1973). A significantly higher dry matter yield of silage was obtained with late hybrids compared to early hybrids in Virginia (Bryant and Blaser, 1968; Lutz and Jones, 1969) and in Nebraska (Colville et al., 1964).

Seedling growth of early hybrids was higher than that of later hybrids, especially under low temperature conditions (MacLean and Donovan, 1973). Therefore, in northern areas where the growing season is relatively cool and short, late maturing hybrids may not produce high yields compared to earlier hybrids, especially if planted late. In southern areas, however, the same late maturing hybrids may exhibit their full genetic potential for yield and outyield the early hybrids.

## Plant Population

While variable, the optimum plant population for silage corn is higher than for grain (Moline, 1975). The optimum plant population for silage ranged from 69,000 to 98,000 plants/ha depending on hybrid and experiment (Bryant and Blaser, 1968; Cummins, 1970; Giesbrecht, 1969; Rutger and Crowder, 1967; Strivers et al., 1971). The yield of silage increased as plant population increased up to the optimum level and then leveled off while grain yield decreased at populations higher than optimum (Termunde et al., 1963).

Specific characteristics of corn such as leaf erectness (Anonymous, 1970), presence or absence of leaf ligules (Pendleton et al., 1968), and capacity to utilize light under different light intensities (Stinson and Moss, 1960) may govern its adaptability to high plant populations, but experimental results are not consistent.

Colville et al. (1964) found that the optimum population for early hybrids (59,300 plants/ha) was higher than for late hybrids (39,500 plants/ha) in grain corn. Lutz and Jones (1969), however, found that the relationship between hybrid and plant population was not consistent between years, hybrids, and locations.

Planting date also may affect the choice of plant population. Aldrich et al. (1975) recommended 2,000-3,000 more plants/ha with extra early planting due to a slightly higher seedling mortality, shorter plants, and improved soil moisture. However, Alessi and Power (1975) found no interaction in yield between planting date and population when corn was planted between May 17 and June 28 in the Northern Plains states.

## Chloroplast Ultrastructure and Physiological Activity under Low Temperature Stress

In corn two types of chloroplasts develop in the mesophyll and vascular bundle sheath cells. Mesophyll cell chloroplasts contain grana which are connected to each other with stromal lamellae to form a continuous membrane system (Paolillo, 1970). Bundle sheath cell chloroplasts are devoid of grana and only a lamellae structure develops although occasionally rudimentary grana are observed (Heath, 1969).

The function of the above chloroplasts apparently changes in the course of leaf development. Kirchanski (1975) found that both mesophyll and bundle sheath cell chloroplasts were morphologically identical in leaf tissue from under the leaf sheath. The young plastids were quite small and generally the same size as mitochondria. Both types of chloroplasts contained starch grains and seemed to function chiefly as amyloplasts.

When relatively immature leaves were exposed to the sun, grana were formed in both mesophyll and bundle sheath cell chloroplasts although the number of granal stacks in the bundle sheath cell chloroplasts were fewer than in the mesophyll cell chloroplasts. In mature leaves, both types of chloroplasts reached their full dimension; grana are well developed in the mesophyll cell chloroplasts and usually do not contain starch grains. In contrast, grana disappeared and starch grains formed in the bundle sheath cell chloroplasts. Also, a well-developed peripheral reticulum (PR) lying under the chloroplast envelope occurred in both types of chloroplasts. This development of PR, which is not common in $C_3$ plants, could be associated with rapid transport of photosynthates from mesophyll cell chloroplasts to bundle sheath cell chloroplasts (Gracen et al., 1972).

When chloroplasts are prepared for electron microscope observation, osmophilic globules or lipid droplets are observed in the chloroplasts following osmium fixation. They are composed primarily of lipophilic chloroplast quinones, α-tocopherylquinone, and vitamin K and form dense deposits lacking a limiting membrane after osmium fixation (Arntzen and Briantais, 1975). These globules increase in number in dark-grown plants and in senescent leaves.

Under low temperature conditions, high light intensity is especially effective in alteration of chloroplast structure. Roberts (1969) found that at 16 C and 2,100 footcandles (fc) normal chloroplasts were developed in a corn hybrid, while at 16 C and 4,100 fc, no grana were observed. Normal greening did not occur after moving the plants to 26 C. Some recovery from the above alteration of chloroplast structure was reported by Klein (1960) who observed that the ring shape structure of chloroplast lamellae from corn grown at 3 C became normal after transferring the plants to 26 C. In sorghum, Taylor and Craig (1971) found that after a cold treatment of 1.5 days at 10 C, mesophyll cell chloroplasts exhibited swelling, a decrease in thylakoid intraspace width, parallel runs of thylakoids, and a reduction in granal stacking. After 2.5 days at 10 C, chloroplasts of mesophyll cells rounded-up or had protuberances, and no grana remained. In chloroplasts of the bundle sheath cells starch grains had disappeared and irregular protuberances developed. Swelling of PR was observed in both mesophyll and bundle sheath cell chloroplasts under low temperature stress.

From a practical standpoint, the relationship between morphological changes in the chloroplast and photosynthetic activity of the plant is of fundamental importance in studying crop yields. Alteration of chloroplast structure (Taylor and Craig, 1971), photodestruction of chlorophyll before its stabilization within the chloroplasts (MacWilliam and Naylor, 1967) and reduced photosynthetic activity (Taylor and Rowley, 1971) were observed under low temperature stress conditions although their interrelationships were not documented.

Taylor and Rowley (1971) found that acclimation of plants to low temperature does occur rapidly. When photosynthesis was measured at 10 C, sorghum which had been grown at 17 C for 8 days showed higher $CO_2$ fixation compared to plants grown at 25 C. Furthermore, when plants were moved from 10 C to 25 C, an increase in photosynthetic activity occurred the next day although complete recovery did not occur.

Under New England growing conditions daily temperature fluctuates around 10 C in the early spring. Thus, the chlorophyll content, the ultrastructure of chloroplasts, and photosynthetic activity may be changing continuously during the growing stages of early planted corn. No specific information is available regarding such changes, their importance to corn growth, or variation which exists between corn hybrids.

# MATERIALS AND METHODS

## Greenhouse Study

### Emergence Test

For the emergence test, nine hybrids of corn were planted in an unsterilized and unfertilized sandy loam soil on 18 Nov. 1976. Twenty seeds were planted at a 5 cm soil depth in 15 cm plastic pots and allowed to germinate at day/night temperatures of 15/10, 20/15, and 26/21 C in the greenhouse. Plant emergence was measured daily until the 24th day after planting. A completely randomized block design with three replications was used at each temperature.

### Growth and Physiological Characteristics

An expanded study was initiated on an early and late hybrid to evaluate their physiological responses to suboptimal temperatures. Four seeds of two silage corn hybrids, Cornell 110 (early) and Agway 590X (late) were planted in 20 cm plastic pots at a 5 cm soil depth on 24 Oct. 1976 and then allowed to germinate at 26/21 C greenhouse. Nine days after emergence plants were thinned to leave two plants in each pot and then allowed to grow at day/night temperatures of 15/10, 20/15, and 26/21 C. Four weeks after initiation of temperature treatments, plant height, leaf number, photosynthesis, chloroplast ultrastructure, chlorophyll content, and dry matter accumulation were measured.

Fertilizer at a rate of 247-107-205 kg/ha of N-P-K and 3.4 metric tons/ha of limestone were incorporated with a steam sterilized sandy loam soil before placing the soil into the pots. A completely randomized block design with four replications was employed at each temperature; an experimental plot consisted of three pots.

## Field Studies

The following three field studies were conducted at different locations in New Hampshire during the 1976 growing season.

### Experiment I: Evaluation of Planting Date

Three silage corn hybrids were planted on five planting dates at two plant populations in a split-split plot with three replications on the University of New Hampshire Agronomy Research Farm, Madbury, N.H. Table 1 gives specific information about the experimental design of Experiment I.

Fertilizer at a rate of 119-49-139 kg/ha of N-P-K and 15 metric tons/ha of manure were applied. Phosphorus, potassium, and manure were applied in the fall of 1975 and the experimental area was plowed in the spring. Nitrogen was applied the day before each planting was made. After planting a mixture of Lasso 4 EC (0.679 kg/ha) and atrazine (0.556 kg/ha) was applied for weed control. The soil was a Charlton loam with 6.4% OM, a P level of 183 ppm, K, Ca, and Mg levels and a cation exchange capacity of 1.2, 4.7,

Table 1. Planting dates, plant populations, and hybrids grown at the University of New Hampshire Agronomy Research Farm, Madbury, N.H.

| | | | |
|---|---|---|---|
| Main plot (planting date) | April 21<br>June 2 | May 5<br>June 16 | May 19 |
| Subplot (plant population) | 76 x 21 cm (62,700 seeds/ha)<br>76 x 16.5 cm (79,700 seeds/ha) | | |
| Sub-subplot (hybrid) | Cornell 110 (early)<br>Wisconsin 335A (medium)<br>Agway 590X (late) | | |

1.7, and 12.6 meg/100 g soil, respectively, and a pH of 5.9.

Emergence of seedlings, percent stand, silking date, soil temperature, and soil moisture were observed. To evaluate early growth of hybrids, dry weights of three plants were determined from each treatment 30 days after each of the respective plantings. Final harvest was made on Sept. 24.

Experiment II: Performance of Hybrids in an Early Planting

Twenty silage corn hybrids widely grown in New Hampshire were planted on April 21 and May 19 in a split plot experiment with three replications; planting date served as main plot and hybrids as subplots.

Fertilizer and herbicide application, soil physical and chemical properties, and experimental observations were similar to those of Experiment I. A plant population of 62,700 seeds/ha was used in 76 cm rows. Final harvest was made on Sept. 18.

Experiment III: Hybrid x Location Interaction

Nine hybrids which were used in Experiment II were grown in West Stewartstown and Groveton (Coos county), North Haverhill (Grafton county), and Westmoreland (Cheshire county) (Figure 1). The annual growing degree days (GDD) of these locations vary from 1,000 to 1,300 C.

The physical and chemical properties of the soils at these locations are shown in Table 2. Planting and harvest dates, plant population, and fertilizer applications are shown in Table 3.

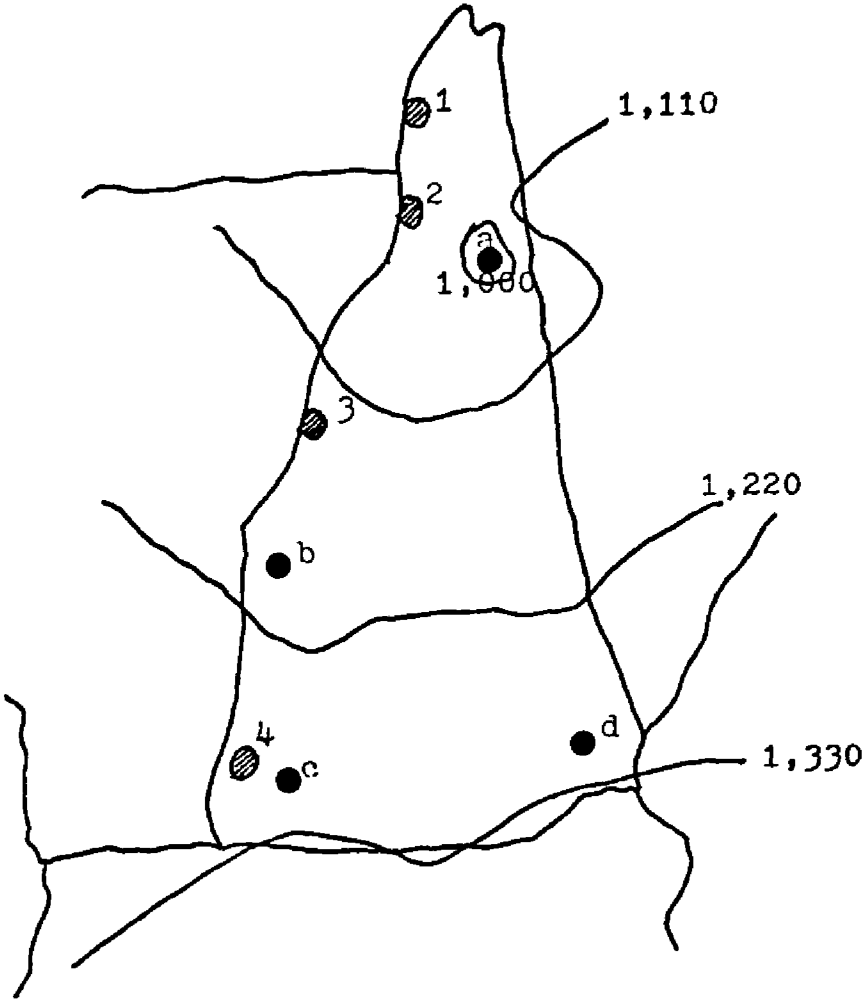
## Laboratory and Other Experimental Procedures

### Temperature and Soil Moisture Measurements

Air temperature and rainfall data were collected on the University of New Hampshire Agronomy Research Farm, Madbury, N.H. throughout the growing season.

Soil temperature was measured at the 10 cm depth from April 21 to June 21 at the site of Experiment II by using a Taylor Model 7601 two point thermograph.

Available soil moisture was measured using Bouyoucos gypsum blocks and a Beckman BN-2B Bouyoucos moisture meter; field capacity of soil moisture is represented as 100% available moisture and wilting point as 20% available moisture.




Experimental locations

1. West Stewartstown, Coos county
2. Groveton, Coos county
3. North Haverhill, Grafton county
4. Westmoreland, Cheshire county

GDD(C) during frost free period

a. Berlin 855
b. Hanover 1074
c. Keene 1067
d. Durham 1161

Fig. 1. Experimental locations and isothermal lines of annual growing degree days (GDD) in New Hampshire. GDD was calculated by the following equation; GDD(C) = ((Max Temp + Min Temp)/2 - 10)) (Kolega and Palmer, 1961).

Table 2. Physical and chemical properties of soil at the four research locations of Experiment III.

| Location | Soil type | pH | P, ppm | K[1] | Ca | Mg | CEC | OM, % |
|---|---|---|---|---|---|---|---|---|
| West Stewartstown | Ondawa loam | 5.6 | 127 | 0.79 | 3.2 | 0.53 | 6.1 | 2.9 |
| Groveton | Groveton silt loam | 6.4 | 18 | 0.54 | 3.9 | 0.82 | 7.4 | 3.8 |
| North Haverhill | Hadley loam | 6.0 | 168 | 0.38 | 4.4 | 0.66 | 9.6 | 3.3 |
| Westmoreland | Hadley loam | 5.8 | 224 | 0.54 | 1.9 | 0.66 | 5.5 | 2.1 |

1 K, Ca, Mg, and CEC, meq/100 g soil.

Table 3. Planting and harvest date, plant population, and fertilization at the four research locations of Experiment III.

| Location | Planting date | Harvest date | Population, seeds/ha | N[1] | P | K | Manure |
|---|---|---|---|---|---|---|---|
| West Stewartstown | May 25 | Oct. 5 | 64,200 | 119 | 30 | 56 | heavy |
| Groveton | May 25 | Oct. 5 | 59,300 | 156 | 36 | 101 | heavy |
| North Haverhill | May 24 | Sept. 30 | 56,800 | 136 | 30 | 84 | heavy |
| Westmoreland | May 21 | Sept. 23 | 56,800 | 180 | 40 | 113 | heavy |

1 N, P, and K fertilization, kg/ha.

## Soil Analyses

Soil samples were collected in the spring of 1976, air dried, and passed through a 2 mm screen (0.2 mm for OM) prior to analyses.

Available P was measured by the method of Olsen and Dean (1965). Cation exchange capacity (CEC) was determined by ammonium saturation (1N $NH_4OAc$ with pH 7.0) and subsequent Kjeldahl distilation. Levels of K and Ca were measured by flame emission and Mg was measured by atomic absorption techniques.

Soil pH was determined on a 1:1 soil to water slurry using a Orion Model 701 pH meter. Soil organic matter (OM) content was measured by the chromic acid techniques as described by Jackson (1958). Soil physical composition was analyzed by the Bouyoucos method (Bouyoucos, 1951) after dispersing the soils with saturated sodium silicate and sodium oxalate.

## Leaf Area Determination

At the silking stage, the green leaves of two plants from each plot in Experiment I and II were measured using a Lambda Model LI-3000 leaf area meter. LAI was calculated by dividing leaf area of two plants by the land area which they occupied.

Chlorophyll Analysis

Three 1 $cm^2$ leaf disks were taken from the middle region of the youngest-mature leaves in the greenhouse experiment and of the April 21 planting in Experiment II. Chlorophyll was extracted with 80% acetone and approximately 0.1 g of $CaCO_3$ in a Virtis 23 homogenizer (The Virtis Co., Gardiner, N.Y.) in a cold room. Absorbance of chlorophyll was measured at the wavelength of 645 and 663 nm in a Beckman DBG spectrophotometer. Chlorophyll content was calculated by the equation of Arnon (1949).

Photosynthesis Measurement

Photosynthesis of the youngest-mature leaves was measured between 1100 and 1300 hours on sunny days using $^{14}CO_2$ (144 Ci/48 litter tank at 1410 psi; New England Nuclear, Boston, Mass.). Leaves were exposed to $^{14}CO_2$ for 30 sec at a flow rate of 120 ml/min using a technique and exposure chamber as described by Incoll and Wright (1969). Immediately after $^{14}CO_2$ exposure, a 1 $cm^2$ leaf disk was punched directly into a liquid scintillation vial containing 1 ml of NCS tissue solubilizer (Amersham/Searle Corp., Arlington Heights, Ill.), and left overnight. One milliliter of benzoyl peroxide bleaching agent was then added (1 g of benzoyl peroxide in 5 ml of toluene), left overnight, and 15 ml of standard fluor solution was added. Activity of $^{14}C$ was measured in a Model 3320 Packard TriCarb liquid scintillation spectrometer for 1 min. Photosynthetic activity was calculated in terms of mg $CO_2/dm^2/hr$.

Electron Microscopy

Four weeks after initiation of temperature treatments in the greenhouse experiment, samples were taken from the middle region of the youngest-mature leaves at 0900 hour.

Leaf sections 1 x 5 mm were cut and fixed in 5% gluteraldehyde in 0.1M phosphate buffer (pH 7.4) for two hours at room temperature. Specimens were subsequently buffer-washed, postfixed in 1% $OsO_4$ (0.1M cacodylate buffer with pH 7.4) for two hours at 4 C, and buffer-washed. Sections were stained in 1% uranyl acetate for 30 min, and dehydrated in a graded ethanol series, 35, 70, 95, 100, and 100% for 15 min each. They were then infiltrated in propylene oxide and Epon 812 at the ratio of 2:1, 1:1, 1:2, and complete resin for one day in each mixture. Samples were embedded in complete resin for 72 hours at 60 C.

Sections were cut using a Sorval Porter-Blum MT-1 ultramicrotome and gold sections (90-150 nm thickness) were taken. Sections were post-stained for four min in saturated uranyl acetate, eight min in lead citrate, and examined with a Philips EM-200 transmission electron microscope.

Relative Maturity (RM) Calculation

For relative maturity of hybrids, growing degree days (GDD) were calculated from planting to 50% silking using the equation of Gilmore and Rogers (1958).

## Yield Determination

After harvest, total fresh weight was measured in the field. To determine percent dry matter three plants were subsampled and dried in an oven at 80 C. Dry matter production was determined by multiplying fresh weight by percent dry matter and expressed as metric tons/ha.

## Statistical Analyses

Experimental design, analysis of variance of the data, and comparison of the means between treatments employed the techniques of Steel and Torrie (1960). The computer facilities of the University of New Hampshire were used for data processing.

# RESULTS

## Climatological Data

Mean air temperature data collected in 1976 on the University of New Hampshire Research Farm, Madbury, N.H. along with the mean air temperature for the 12 year period (1965-1976) are shown in Figure 2. The long-term average temperature was about 10 C in early May, increased during May and June, remained at about 22 C during July and August, and decreased to about 13 C by the end of September. In 1976, air temperature fluctuated around the long-term average but was generally higher than the long-term average from May to early July. From late July to September of 1976, air temperatures were lower than the long-term average.

The maximum and minimum air temperatures during the period from April 21 to June 21 in 1976 are shown in Figure 3. Generally, the maximum air temperature in May was higher than 15 C, while night temperature dropped below 10 C. No spring frost occurred after late April in 1976. Generally, the minimum soil temperature was higher than the minimum air temperature during the spring. The highly significant positive correlation between minimum soil and air temperature is shown in Figure 4.

Rainfall and available soil moisture during the cropping season of 1976 are shown in Figure 5. Soil moisture stress occurred during the middle of June to early July.

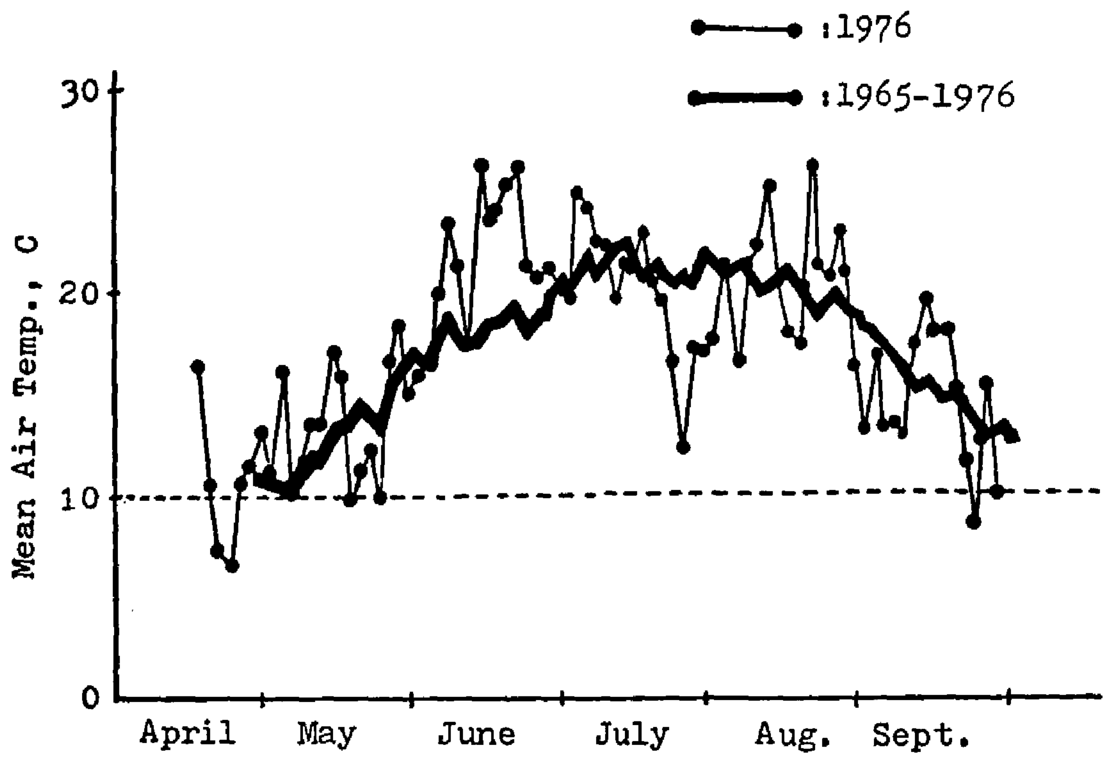



Fig. 2. Mean air temperature at the University of New Hampshire Agronomy Research Farm, Madbury, N.H. Each data point represents the average of two days.

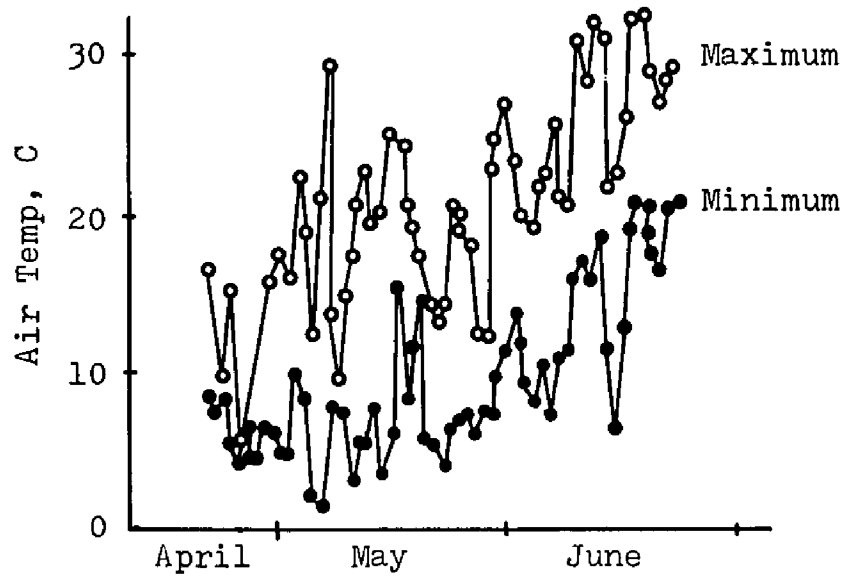



Fig. 3. Daily maximum and minimum air temperatures from 21 April to 21 June 1976 on the University of New Hampshire Agronomy Research Farm, Madbury, N.H.

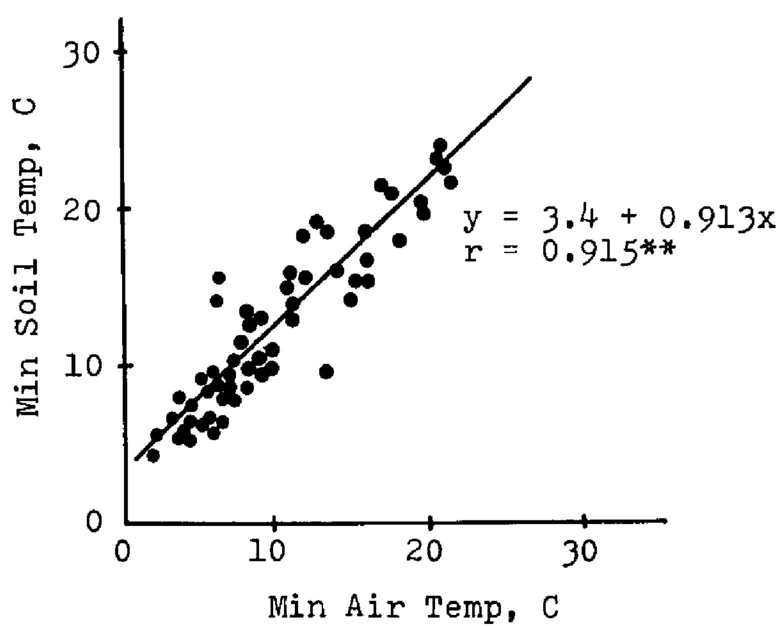



Fig. 4. Relationship between minimum air and soil temperatures from 21 April to 21 June 1976 on the University of New Hampshire Agronomy Research Farm, Madbury, N.H. Soil temperature was measured at the 10 cm soil depth.

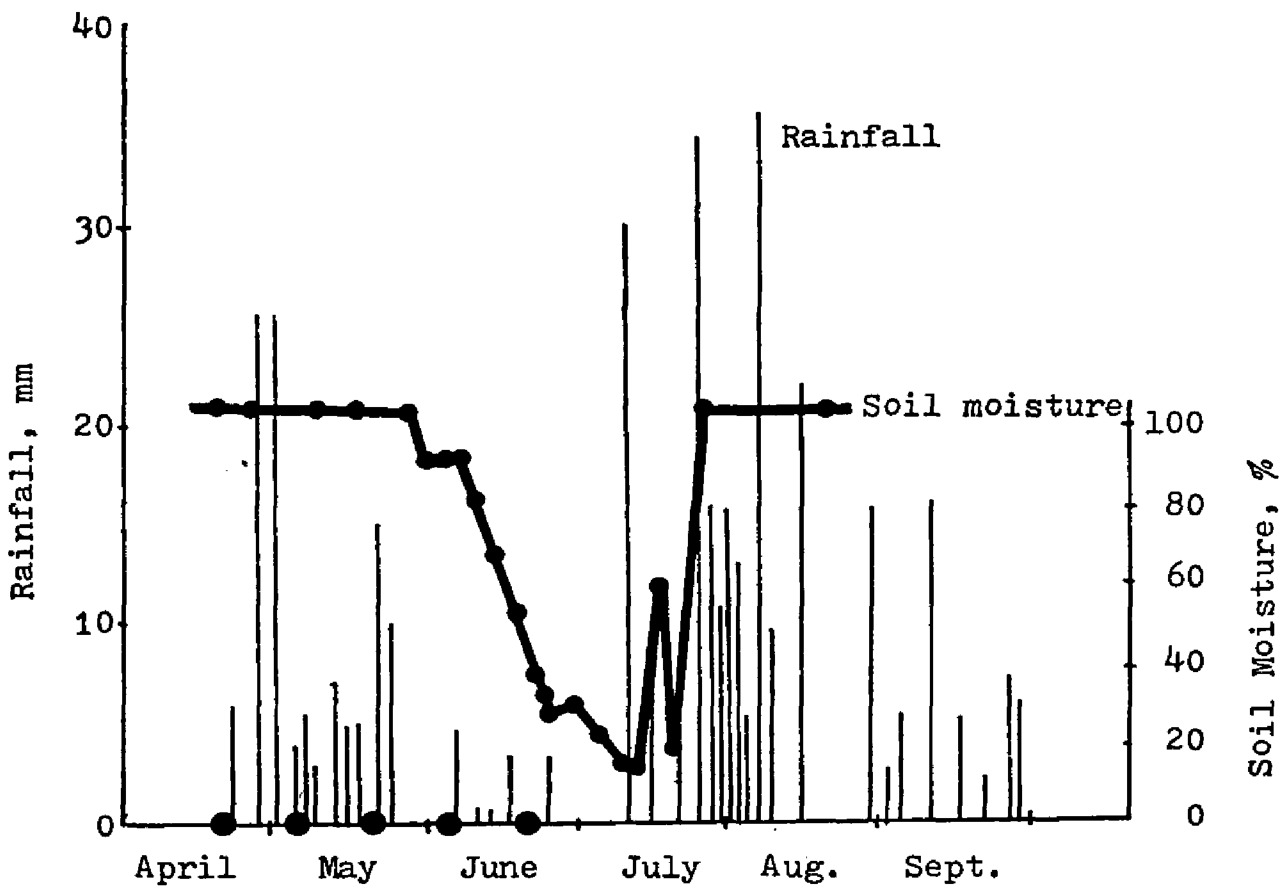



Fig. 5. Rainfall and available soil moisture during the 1976 cropping season on the UNH Agronomy Research Farm, Madbury, N.H. ● represents planting dates.

## Greenhouse Study

### Emergence Test

Percent emergence of 9 hybrids at three greenhouse temperatures is shown in Table 4. Percent emergence of Agway 393S was significantly lower than other hybrids at all temperatures although no indication of a poorer germination percentage was evident. Emergence of Asgrow RX-35A was lower than other hybrids at 15/10 and 20/15 C but not at 26/21 C. For the remaining hybrids there were no significant differences in percent emergence at all temperatures except the lower percent emergence of Stewart 2501 at 15/10 C.

Table 4. Percent emergence of 9 corn hybrids at three day/night temperatures measured 24 days after planting.

| | Temperature, C | | |
|---|---|---|---|
| Hybrid | 15/10 | 20/15 | 26/21 |
| Cornell 110 | 73.3 abc | 96.7 a | 93.3 a |
| Stewart 2501 | 63.3 bcd | 91.7 a | 90.0 a |
| Seneca 140 | 81.7 ab | 91.7 a | 95.0 a |
| Asgrow RX-35A | 55.0 cd | 80.0 b | 93.3 a |
| Wisc. 335A | 75.0 abc | 93.3 a | 95.0 a |
| NK PX-446 | 93.3 a | 98.3 a | 95.0 a |
| Agway 393S | 48.3 d | 66.7 c | 68.3 b |
| Agway 590X | 93.3 a | 96.7 a | 91.7 a |
| Old Fox 1105 | 88.3 a | 98.3 a | 96.7 a |

Means within a column followed by the same letter are not significantly different at the 5% level by Duncan's new multiple range test (DNMRT).

Time from planting to 80% emergence of the hybrids is shown in Table 5. At 15/10 C, five hybrids did not reach the 80% emergence until 24 days after planting; four hybrids took 16 to 23 days for emergence. At 20/15 C, all hybrids took 10 to 13 days, except for Agway 393S. At 26/21 C, 6 to 7 days were required to achieve 80% emergence by all hybrids, except Agway 393S whose percent emergence did not reach 80% until 24 days after planting.

Table 5. Days from planting to 80% emergence of 9 hybrids at three day/night temperatures.

| | Temperature, C | | |
|---|---|---|---|
| Hybrid | 15/10 | 20/15 | 26/21 |
| Cornell 110 | - | 10 | 7 |
| Stewart 2501 | - | 10 | 7 |
| Seneca 140 | 20 | 10 | 6 |
| Asgrow RX-35A | - | 13 | 7 |
| Wisc. 335A | - | 13 | 7 |
| NK PX-446 | 16 | 10 | 7 |
| Agway 393S | - | - | - |
| Agway 590X | 19 | 11 | 7 |
| Old Fox 1105 | 23 | 11 | 7 |

The reason why the percent emergence of Agway 393S was lower than other hybrids at all temperatures is unknown since all were 1976 seeds with germinations certified at 90% or greater.

Generally, percent emergence was lower and emergence speed was slower at 15/10 C compared to that at 20/15 or 26/21 C. Percent emergence of the hybrids at

20/15 C was similar to that at 26/21 C during the 24 day period after planting although growth at the lower temperature was delayed by 4 to 6 days compared to that at 26/21 C.

<u>Growth and Physiological Characteristics</u>

The number of leaves, plant height, dry weight, chlorophyll content, photosynthetic activity, and N concentration and content of an early and a late-maturing hybrid grown at three temperatures are shown in Table 6. At the lowest temperature, 15/10 C, the number of leaves, plant height, dry weight, and N content of the early hybrid, Cornell 110, were higher than those of the late hybrid, Agway 590X. However, no significant differences occurred in chlorophyll content, photosynthetic activity, and N concentration between the two hybrids. At 20/15 C, plant height and dry weight of Cornell 110 were higher than those of Agway 590X, but photosynthetic activity of Agway 590X was significantly higher than that of Cornell 110 and no differences occurred in chlorophyll content between the two hybrids. At the more favorable temperature for corn growth, 26/21 C, no differences occurred in any of the physiological characters between the two hybrids. At the suboptimal temperature the early hybrid was clearly more vigorous than the later hybrid.

The influence of two temperature treatments on the ultrastructure of chloroplasts of leaves from

Table 6. Number of leaves, plant height, dry weight, chlorophyll content, photosynthetic activity, and N concentration and content of two corn hybrids grown at three day/night temperatures four weeks after initiation of temperature treatments.

| | Temperature, C | | |
|---|---|---|---|
| Hybrid | 15/10 | 20/15 | 26/21 |
| | Number of leaves | | |
| Cornell 110 | 4.5 a | 5.5 a | 6.7 a |
| Agway 590X | 4.3 b | 5.5 a | 6.5 a |
| | Plant height, cm | | |
| Cornell 110 | 35.7 a | 55.7 a | 69.2 a |
| Agway 590X | 28.7 b | 52.2 b | 69.1 a |
| | Dry weight, g/6 plants | | |
| Cornell 110 | 2.6 a | 5.4 a | 9.5 a |
| Agway 590X | 1.8 b | 4.9 b | 8.7 a |
| | Total chlorophyll, $mg/dm^2$ | | |
| Cornell 110 | 2.5 a | 2.7 a | 2.9 a |
| Agway 590X | 2.4 a | 2.9 a | 3.2 a |
| | Photosynthesis, mg $CO_2/dm^2/hr$ | | |
| Cornell 110 | 11.5 a | 14.5 b | 19.2 a |
| Agway 590X | 8.9 a | 25.1 a | 23.5 a |
| | N, % | | |
| Cornell 110 | 4.0 a | 3.6 a | 3.5 a |
| Agway 590X | 4.0 a | 3.2 a | 3.3 a |
| | N, mg/plant | | |
| Cornell 110 | 17.4 a | 32.0 a | 55.4 a |
| Agway 590X | 11.8 b | 26.6 b | 47.1 a |

Means in a column for a given character followed by the same letter are not significantly different at the 5% level.

seedlings of Agway 590X and Cornell 110 is shown in Figures 6, 7, 8, and 9. Chloroplast ultrastructure of the later-maturing hybrid, Agway 590X, was significantly altered at the lower day/night temperature of 15/10 C (Figure 6). In the mesophyll cell chloroplasts were rounded-up, the number of granal stacks and stromal lamellae was significantly reduced, and the number of osmophilic globules increased. In the bundle sheath cell chloroplasts, irregular protuberances occurred, interlamellar spaces were swelled, and several rudimentary grana were formed compared to the chloroplast structure of Agway 590X grown at 20/15 C. In both the mesophyll and bundle sheath cell chloroplasts, the peripheral reticulum was swelled and some disconnected lamellae were found. None of these chloroplast alterations were observed in Agway 590X grown at 20/15 (Figure 7) or in Cornell 110 grown at either 15/10 (Figure 8) or 20/15 C (Figure 9).

## Field Studies

### Experiment I: Evaluation of Planting Date

Emergence date, days from planting to emergence, average mean soil temperature, and growing degree days (GDD) from planting to emergence for five planting dates are shown in Table 7. Days from planting to emergence decreased as planting was delayed. GDD calculated from air temperature was quite similar among planting dates. However, soil temperatures during the emergence period were


Fig. 6. Chloroplast ultrastructure of leaves from seedlings of Agway 590X grown at a day/night temperature of 15/10 C for four weeks. Magnification: x 17,500.

A: Mesophyll cell chloroplast; rounded shape, reduced number of granal stacks (G) and stromal lamellae (SL), swelled peripheral reticulum (PR), some disconnected SL, and swelled interlamellar spaces.
B: Bundle sheath cell chloroplast; irregular protuberances (PB), occurrence of rudimentary grana (RG), swelled PR, and swelled interlamellar spaces.

CW; cell wall, M; mitochondria, OG, osmophilic globules.

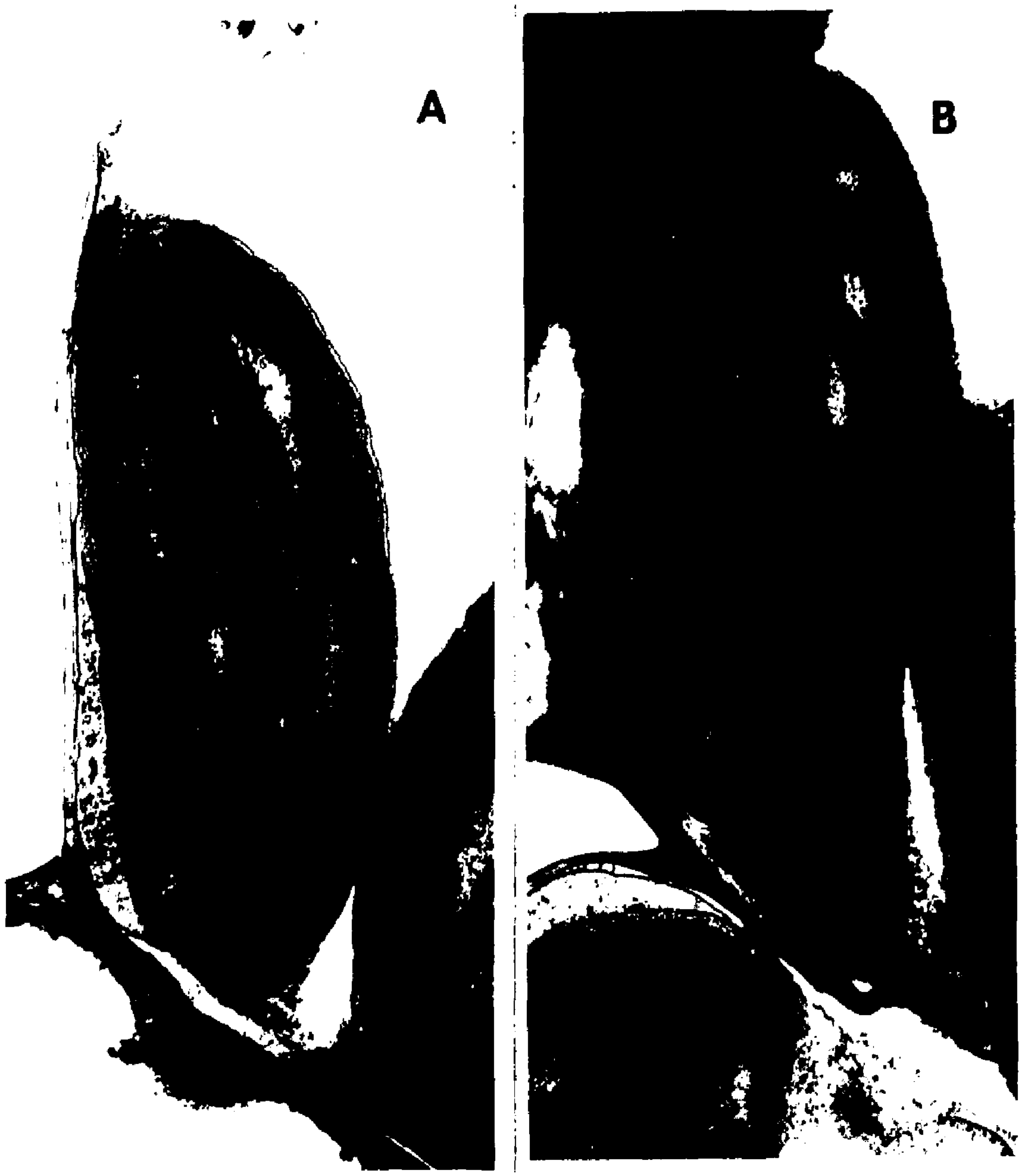



Fig. 7. Chloroplast ultrastructure of leaves from seedlings of Agway 590X grown at a day/night temperature of 20/15 C for four weeks. Magnification: x 17,500.

A: Mesophyll cell chloroplast.
B: Bundle sheath cell chloroplast.

No structural abnormalities.

Fig. 8. Chloroplast ultrastructure of leaves from seedlings of Cornell 110 grown at a day/night temperature of 15/10 C for four weeks. Magnification: x 17,500.

A: Mesophyll cell chloroplast.
B: Bundle sheath cell chloroplast.

No structural abnormalities: M; mitochondria, G; grana, OG; osmophilic globules, CW; cell wall, PR; peripheral reticulum, N; nucleus.

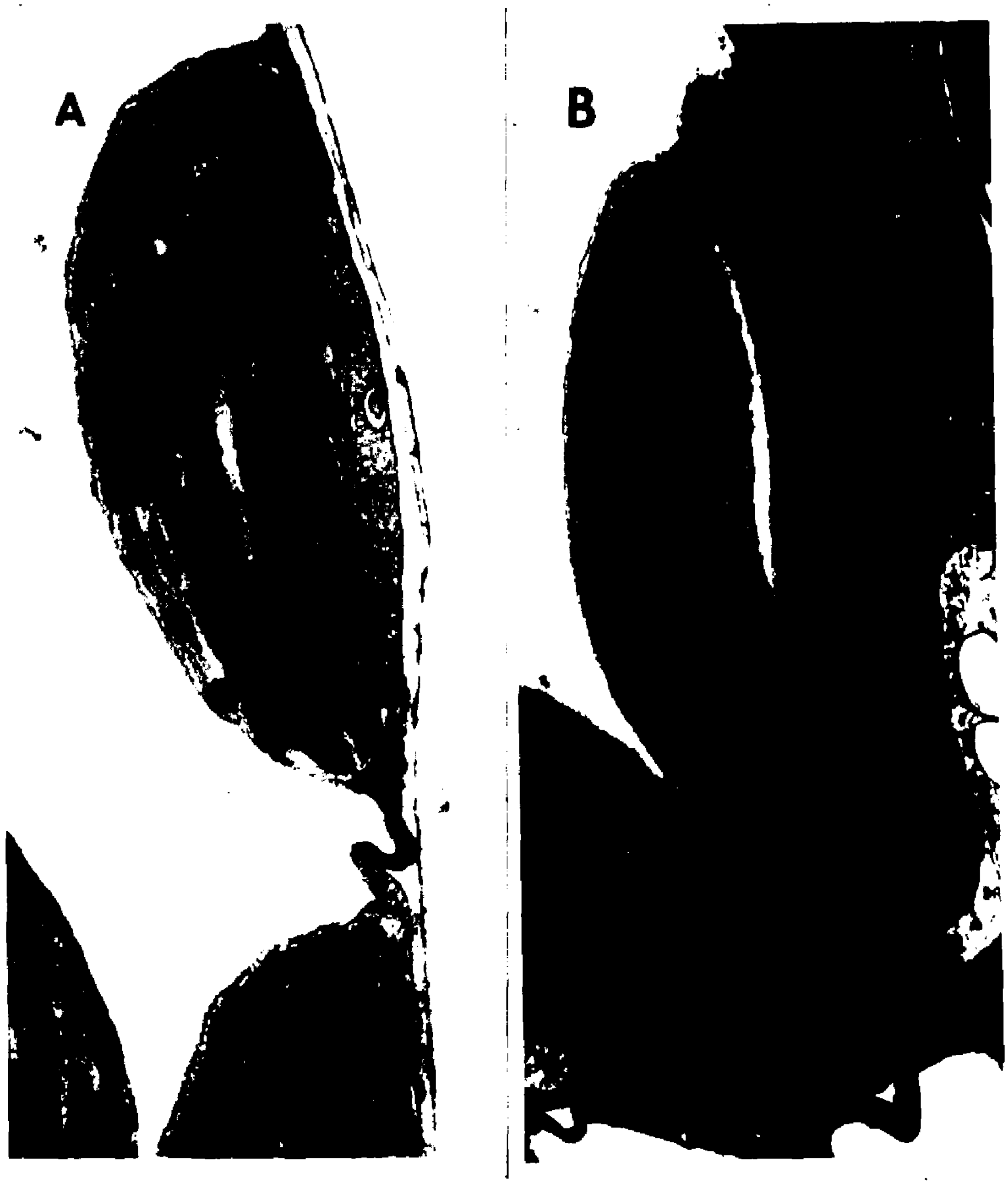



Fig. 9. Chloroplast ultrastructure of leaves from seedlings of Cornell 110 grown at a day/night temperature of 20/15 C for four weeks. Magnification: x 17,500.

A: Mesophyll cell chloroplast.
B: Bundle sheath cell chloroplast.

No structural abnormalities.

closely correlated to the emergence time; a reciprocal of days to emergence was linearly proportional to the reciprocal of mean soil temperature as expressed in degrees Kelvin (Figure 10).

Table 7. Effect of planting date on emergence, average mean soil temperature and GDD from planting to emergence for five planting dates. Each figure represents the average of three hybrids.

| Planting date | Emergence date | Days to emergence | Avg mean soil temp, C | GDD, C |
|---|---|---|---|---|
| April 21 | May 9 | 18 | 10.3 | 54.9 |
| May 5 | May 16 | 11 | 13.9 | 62.5 |
| May 19 | May 30 | 11 | 14.1 | 52.0 |
| June 2 | June 9 | 7 | 19.7 | 60.5 |
| June 16 | June 21 | 5 | 26.4 | 70.3 |

Analysis of variance for percent stand, dry weight of plants 30 days after emergence, total dry matter (TDM), stover, and ear yield, % dry matter (% DM), ear-to-TDM ratio at harvest, and LAI at silking are shown in Table 8. No significant differences occurred between two plant populations in all characters except lower % DM and higher LAI at the higher plant population. Also, no significant interactions occurred with plant population and other factors. Thus, the results of two plant populations were averaged in all characters.

Percent stand of three hybrids, Cornell 110 (early), Wisc. 335A (medium), and Agway 590X (late), at four dates of planting is shown in Table 9. No significant differences occurred in percent stand among hybrids. Percent

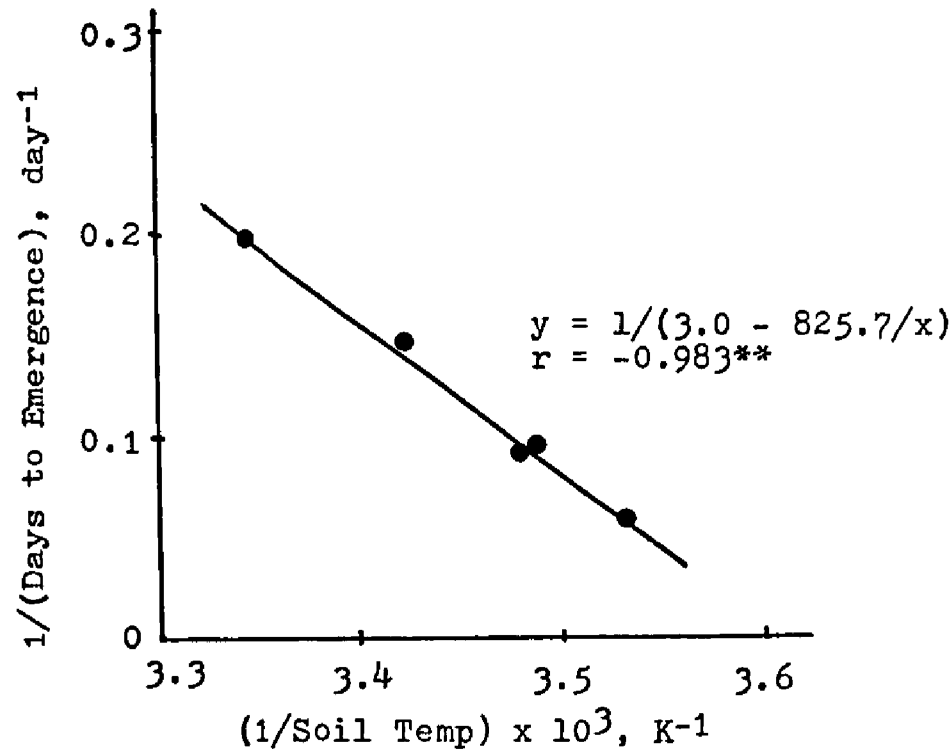



Fig. 10. Relationship between the reciprocal of mean soil temperature and the reciprocal of time to emergence for five planting dates.

Table 8. Analysis of variance for percent stand, plant dry weight 30 days after emergence, TDM yield, stover yield, ear yield, % DM, ear-to-TDM ratio at harvest, and LAI at silking of Experiment I, UNH Agronomy Research Farm, Madbury, N.H.

| | | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | df | % stand | Dry wt[1] | TDM yield | Stover yield | Ear yield | % DM | Ear-to-TDM ratio | LAI |
| Main plot | | | | | | | | | |
| Replication, R | 2 | 2.5 | 25.7 | 1.5 | 0.9 | 0.3 | 0.4 | 30.1 | 0.1 |
| Planting, P | 3 | 522.9* | 3637.1* | 3.7 | 4.7 | 4.9 | 435.0** | 147.0** | 0.6* |
| Error | 6 | 54.8 | 10.5 | 5.2 | 2.4 | 1.1 | 7.2 | 4.8 | 0.1 |
| Subplot | | | | | | | | | |
| Population, D | 1 | 9.9 | 0.5 | 2.4 | 0.1 | 1.5 | 46.1** | 7.4 | 12.3** |
| P x D | 3 | 47.3 | 5.8 | 1.3 | 0.8 | 0.3 | 5.3 | 4.3 | 0.4 |
| Error | 8 | 13.7 | 20.1 | 4.3 | 0.8 | 2.2 | 1.7 | 9.0 | 0.1 |
| Sub-subplot | | | | | | | | | |
| Hybrid, H | 2 | 36.5 | 43.7* | 102.0** | 27.8** | 21.7** | 299.6** | 94.6** | 8.4** |
| H x P | 6 | 22.5 | 13.8 | 4.5 | 2.4 | 1.9 | 11.4 | 4.8 | 0.0 |
| H x D | 2 | 8.5 | 9.2 | 3.9 | 0.4 | 1.4 | 11.3 | 10.3 | 0.0 |
| H x P x D | 6 | 43.2 | 10.7 | 4.2 | 0.7 | 1.8 | 2.9 | 4.0 | 0.1 |
| Error | 32 | 30.4 | 9.5 | 2.3 | 1.2 | 1.1 | 7.6 | 14.6 | 0.1 |

1 Dry weight 30 days after emergence.
*, ** Significant at the 5 and 1% levels, respectively.

stand of the June 2 planting was significantly lower than the three earlier plantings because available soil moisture was especially low during the emergence period of this planting (Figure 5); no irrigation water was applied. Because of extremely poor emergence, results of the June 16 planting were excluded from the experiment.

Table 9. Percent stand of three corn hybrids at four planting dates. Each figure represents the average of two plant populations.

| | Planting date | | | | |
|---|---|---|---|---|---|
| Hybrid | April 21 | May 5 | May 19 | June 2 | Average |
| Cornell 110 | 87.3 | 86.7 | 88.9 | 77.1 | 85.0 a |
| Wisc. 335A | 88.6 | 82.0 | 85.2 | 76.6 | 83.1 a |
| Agway 590X | 86.1 | 86.3 | 85.2 | 73.2 | 82.7 a |
| Average | 87.3 A | 85.0 A | 86.4 A | 75.6 B | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

The dry weights of plants harvested 30 days after emergence for four plantings are shown in Table 10. The accumulated GDD during the above 30-day growth period for the April 21, May 5, May 19, and June 2 plantings was 179, 212, 335, and 373 C, respectively. Growth of plants during the first 30 days after emergence markedly increased as planting was delayed; when planted on April 21 and May 5 plants grew very little during the first 30 days after emergence compared to the two later plantings. The dry

Table 10. Dry weight of three hybrids 30 days after emergence at four planting dates. Each figure represents the average of two plant populations.

| Hybrid | Planting date: April 21 | May 5 | May 19 | June 2 | Average |
|---|---|---|---|---|---|
| | | | g/plant | | |
| Cornell 110 | 1.9 | 5.3 | 22.7 | 35.7 | 16.4 a |
| Wisc. 335A | 1.9 | 5.5 | 20.2 | 29.0 | 14.2 b |
| Agway 590X | 1.6 | 4.0 | 20.0 | 31.0 | 14.2 a |
| Average | 1.8 D | 4.9 C | 21.0 B | 31.9 A | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

weight of the earliest hybrid, Cornell 110, was higher than the latest hybrid, Agway 590X, at all planting dates. The intermediate hybrid in terms of seasonal maturity, Wisc. 335A, had growth similar to the early hybrid in the two earlier plantings but was similar to the late hybrid in the two later plantings.

The LAI at silking for each of three hybrids at four planting dates is shown in Table 11. LAI of the dense planting (79,700 seeds/ha) was significantly higher than that of normal plant population (62,700 seeds/ha); 4.2 vs 3.4.

In comparing planting dates, LAI of plants from the May 19 planting was higher than either the earlier or later planting. Among hybrids, LAI increased with delayed maturity of hybrids.

Table 11. LAI of three corn hybrids at silking at four planting dates. Each figure represents the average of two plant populations.

| Hybrid | Planting date April 21 | May 5 | May 19 | June 2 | Average |
|---|---|---|---|---|---|
| Cornell 110 | 3.1 | 3.1 | 3.4 | 3.2 | 3.2 c |
| Wisc. 335A | 3.6 | 3.8 | 4.2 | 4.1 | 3.9 b |
| Agway 590X | 4.1 | 4.3 | 4.6 | 3.9 | 4.2 a |
| Average | 3.6 B | 3.7 B | 4.1 A | 3.7 B | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

TDM and ear yield, % DM, and ear-to-TDM ratio of three hybrids at four planting dates are shown in Table 12. No significant differences occurred in TDM and ear yield among the planting dates. However, % DM and ear-to-TDM ratio of plants from the two early plantings were higher than those of the late plantings. When hybrids are compared, the TDM and ear yields were highest with the hybrid Agway 590X, and lowest with Wisc. 335A. However, % DM and ear-to-TDM ratio were directly related to earliness of the hybrids.

Experiment II: Performance of Hybrids in an Early Planting

Maturity of hybrids was not known at the site of Experiment II. Thus, relative maturity (RM) of the 20 corn hybrids was computed from planting to silking in terms of GDD. RM, silking dates, and GDD from silking to harvest

Table 12. TDM and ear yield, % DM, and ear-to-TDM ratio of three corn hybrids at four planting dates. Each figure represents the average of two plant populations.

| Hybrid | Planting date: April 21 | May 5 | May 19 | June 2 | Average |
|---|---|---|---|---|---|
| | | TDM, metric tons/ha | | | |
| Cornell 110 | 14.3 | 14.1 | 16.0 | 13.4 | 14.5 b |
| Wisc. 335A | 13.9 | 12.7 | 13.0 | 13.5 | 13.3 c |
| Agway 590X | 17.3 | 18.6 | 17.2 | 16.8 | 17.4 a |
| Average | 15.1 A | 15.1 A | 15.7 A | 14.6 A | |
| | | Ear yield, metric tons/ha | | | |
| Cornell 110 | 9.0 | 8.9 | 9.3 | 8.0 | 8.8 b |
| Wisc. 335A | 8.8 | 8.0 | 7.9 | 7.6 | 8.0 c |
| Agway 590X | 10.2 | 11.1 | 9.4 | 9.0 | 9.9 a |
| Average | 9.3 A | 9.3 A | 8.9 A | 8.2 A | |
| | | % DM | | | |
| Cornell 110 | 48.7 | 44.3 | 39.2 | 36.8 | 42.2 a |
| Wisc. 335A | 47.1 | 43.9 | 36.7 | 34.3 | 40.5 b |
| Agway 590X | 39.2 | 37.7 | 32.5 | 32.3 | 35.4 c |
| Average | 45.0 A | 42.0 B | 36.1 C | 34.5 C | |
| | | Ear-to-TDM ratio, % | | | |
| Cornell 110 | 63.3 | 62.2 | 58.2 | 59.5 | 60.8 a |
| Wisc. 335A | 63.0 | 62.3 | 57.4 | 56.1 | 59.7 a |
| Agway 590X | 59.1 | 59.8 | 54.6 | 54.1 | 56.9 b |
| Average | 61.8 A | 61.4 A | 56.8 B | 56.5 B | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

are shown in Table 13. Among hybrids, RM ranged from 632 to 783 C and silking dates ranged from July 12 to August 4.

The analysis of variance for percent stand, dry weight 30 days after emergence, TDM, stover yield, and ear yield, % DM, ear-to-TDM ratio at harvest, and LAI at silking are shown in Table 14. Planting date and choice of hybrid produced variable responses in the observed characters. Thus, they will be presented in detail.

Percent stand of 20 corn hybrids at two planting dates is shown in Table 15. No significant differences occurred in percent stand between planting dates and among hybrids except Asgrow RX-35A, Seneca 285, and Agway 393S which were about 5-10% lower than other hybrids at both planting dates.

To evaluate early growth, the dry weight of each hybrid was determined 30 days after emergence for each planting (Table 16 and Figure 11). In the April 21 planting, two of the earliest hybrids, Cornell 110 and Stewart 2501, showed higher dry weights than the other hybrids. In the May 19 planting, early growth was negatively correlated to the RM of hybrids in terms of GDD. Temperatures were quite different between the two plantings; accumulated GDD for the first 30 days after emergence was 179 C for the April 21 planting and 335 C for the May 19 planting. Photosynthetic rates among hybrids in the field and total chlorophyll contents of the youngest-mature leaves 30 days after

Table 13. Relative maturity (RM), silking date, and GDD from silking to harvest of 20 corn hybrids at two planting dates on the UNH Research Farm, Madbury, N.H., 1976.

| Hybrid | RM[1] (GDD), C | Silking date 4/21 | Silking date 5/19[2] | GDD, C[3] 4/21 | GDD, C[3] 5/19 |
|---|---|---|---|---|---|
| Cornell 110 | 632 | 7/12 | 7/18 | 652 | 586 |
| Cornell 103 | 644 | 7/13 | 7/19 | 642 | 574 |
| Stewart 2501 | 645 | 7/12 | 7/20 | 652 | 560 |
| Seneca 140 | 648 | 7/14 | 7/19 | 633 | 574 |
| Minhybrid 806 | 650 | 7/13 | 7/20 | 642 | 560 |
| Old Fox 905 | 656 | 7/13 | 7/21 | 642 | 549 |
| Funk 5048 | 666 | 7/15 | 7/21 | 621 | 549 |
| Asgrow RX-29 | 671 | 7/15 | 7/22 | 621 | 540 |
| Asgrow RX-35A | 671 | 7/15 | 7/22 | 621 | 540 |
| Dekalb XL-12 | 674 | 7/15 | 7/23 | 621 | 533 |
| Wisc. 335A | 701 | 7/17 | 7/26 | 596 | 505 |
| NK PX-446 | 712 | 7/19 | 7/26 | 574 | 505 |
| Seneca 285 | 712 | 7/19 | 7/26 | 574 | 505 |
| Agway 393S | 725 | 7/20 | 7/27 | 560 | 492 |
| NK PX-32 | 731 | 7/21 | 7/27 | 549 | 492 |
| Dekalb XL-43 | 731 | 7/20 | 7/28 | 560 | 481 |
| Agway 595S | 731 | 7/20 | 7/28 | 560 | 481 |
| Agway 590X | 741 | 7/21 | 7/29 | 549 | 472 |
| Old Fox 1105 | 769 | 7/26 | 8/1 | 505 | 452 |
| Dekalb XL-640 | 783 | 7/27 | 8/4 | 492 | 428 |

1 Relative maturity from planting to silking as the average of two planting dates.
2 Planting dates.
3 GDD from silking to harvest.

Table 14. Analysis of variance for percent stand, plant dry weight 30 days after emergence, TDM yield, stover yield, ear yield, % DM, ear-to-TDM ratio at harvest, and LAI at silking of Experiment II, UNH Agronomy Research Farm, Madbury, N.H.

| | | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Source | df | % stand | Dry wt[1] | TDM yield | Stover yield | Ear yield | % DM | Ear-to-TDM ratio | LAI |
| Main plot | | | | | | | | | |
| Replication, R | 2 | 117.8 | 20.1 | 2.6 | 2.9 | 0.0 | 36.3 | 34.9 | 0.0 |
| Planting, P | 1 | 49.8 | 10,230.5** | 6.1 | 9.2 | 29.5** | 868.3** | 598.1** | 0.8 |
| Error | 2 | 124.7 | 16.3 | 4.3 | 3.6 | 0.4 | 3.5 | 43.7 | 0.4 |
| Subplot | | | | | | | | | |
| Hybrid, H | 19 | 89.6** | 22.3** | 21.3** | 17.4** | 2.6 | 140.7** | 165.5** | 1.7** |
| H x P | 19 | 33.1 | 19.1** | 2.6 | 0.8 | 1.4 | 13.7 | 15.8 | 0.1 |
| Error | 76 | 33.9 | 3.7 | 3.3 | 1.0 | 1.5 | 8.2 | 14.4 | 0.1 |

1 Dry weight 30 days after emergence.
*, ** Significant at the 5 and 1% levels, respectively.

Table 15. Percent stand of 20 corn hybrids at two planting dates.

| | Planting date | | |
|---|---|---|---|
| Hybrid | April 21 | May 19 | Average |
| Cornell 110 | 95.5 | 87.9 | 91.7 abc |
| Cornell 103 | 95.5 | 95.5 | 95.5 a |
| Stewart 2501 | 95.5 | 86.4 | 90.9 abc |
| Seneca 140 | 94.0 | 86.4 | 90.2 abc |
| Minhybrid 806 | 89.4 | 92.4 | 90.9 abc |
| Old Fox 905 | 93.9 | 93.9 | 93.9 ab |
| Funk 5048 | 95.5 | 86.4 | 90.9 abc |
| Asgrow RX-29 | 92.5 | 94.0 | 93.2 ab |
| Asgrow RX-35A | 80.3 | 87.9 | 84.1 cd |
| Dekalb XL-12 | 97.0 | 95.5 | 96.2 a |
| Wisc. 335A | 95.5 | 92.4 | 94.0 ab |
| NK PX-446 | 94.0 | 94.0 | 94.0 ab |
| Seneca 285 | 78.8 | 81.8 | 80.3 d |
| Agway 393S | 87.9 | 84.9 | 86.4 bcd |
| NK PX-32 | 95.5 | 90.9 | 93.2 ab |
| Dekalb XL-43 | 92.4 | 95.5 | 94.0 ab |
| Agway 595S | 95.5 | 92.5 | 93.2 ab |
| Agway 590X | 92.5 | 92.4 | 92.5 ab |
| Old Fox 1105 | 89.4 | 94.0 | 91.7 abc |
| Dekalb XL-640 | 92.4 | 94.0 | 93.2 ab |
| Average | 92.1 A | 90.8 A | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

Table 16. Dry weight of 20 corn hybrids 30 days after emergence at two planting dates. Four plants were sampled in each plot.

| | Planting date | |
|---|---|---|
| Hybrid | April 21 | May 19 |
| | g/plant | |
| Cornell 110 | 2.2 a | 25.2 ab |
| Cornell 103 | 1.6 bc | 27.9 a |
| Stewart 2501 | 1.9 b | 19.4 cde |
| Seneca 140 | 1.0 ef | 25.0 ab |
| Minhybrid 806 | 1.4 cde | 23.2 bc |
| Old Fox 905 | 1.4 cde | 19.2 cde |
| Funk 5048 | 1.0 ef | 18.2 cde |
| Asgrow RX-29 | 1.3 cde | 19.4 cde |
| Asgrow RX-35A | 1.5 bcd | 21.2 cde |
| Dekalb XL-12 | 1.2 def | 18.5 cde |
| Wisc. 335A | 1.2 def | 22.7 bc |
| NK PX-446 | 1.3 cde | 16.4 def |
| Seneca 285 | 0.8 f | 13.0 f |
| Agway 393S | 1.3 cde | 15.7 ef |
| NK PX-32 | 1.3 cde | 21.2 bcd |
| Dekalb XL-43 | 1.4 cde | 19.2 cde |
| Agway 595S | 1.1 ef | 16.4 def |
| Agway 590X | 1.2 def | 17.0 def |
| Old Fox 1105 | 1.3 cde | 16.4 def |
| Dekalb XL-640 | 1.2 def | 17.4 def |

Means in a column followed by the same letter are not significantly different at the 5% level by DNMRT.

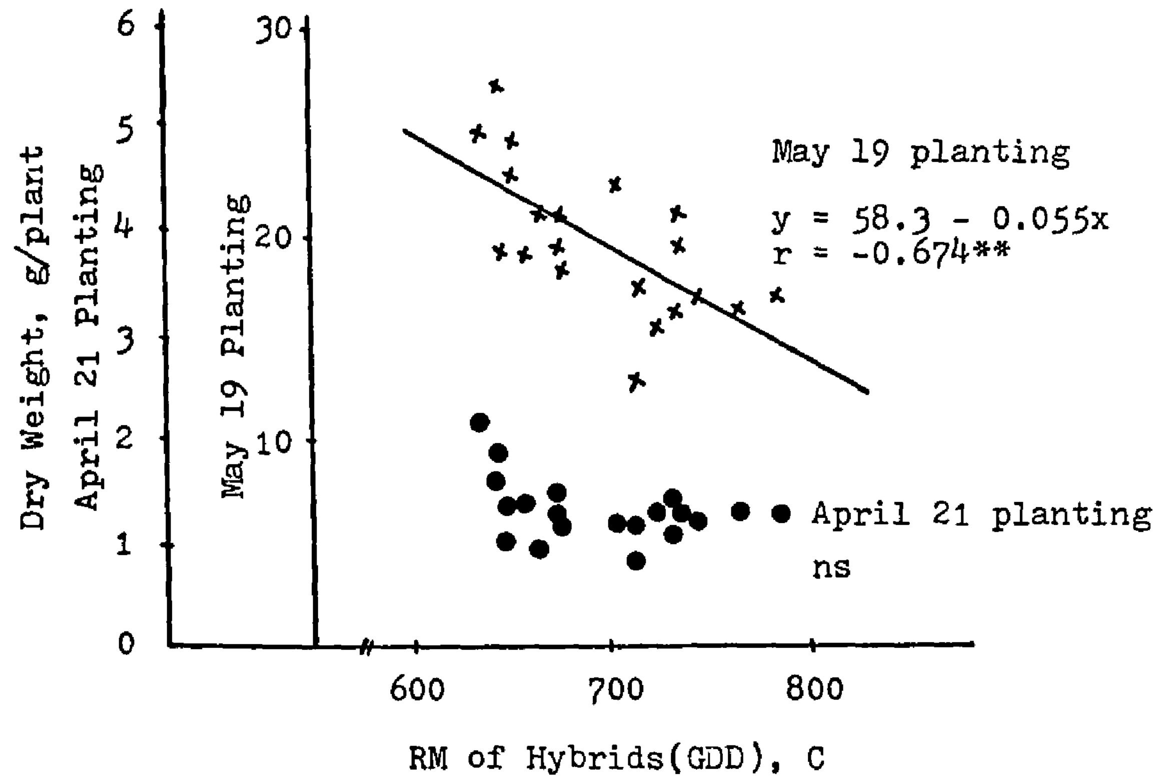



Fig. 11. Relationships between relative maturity(RM) of 20 corn hybrids and shoot weight 30 days after emergence at two planting dates.

emergence of the April 21 planting were not significantly different (Table 17).

TDM, and ear yield, ear-to-TDM ratio, and % DM at fall harvest are shown in Tables 18, 19, 20, and 21, respectively. Date of planting affected TDM and ear yield differently. TDM was similar between planting dates, but ear yield was higher in the April 21 planting compared to the May 19 planting. Such results indicate that the relative yield of stover was lower in the April 21 planting compared to May 19 planting giving a higher ear-to-TDM ratio in the earlier planting.

Because no significant interactions existed between hybrid and planting date for all characters, the two planting dates were averaged. The relationships between RM of hybrids and TDM, ear yield, ear-to-TDM ratio, and % DM are shown in Figure 12. Yields of TDM were directly related to the maturity of the hybrids, while ear yield was not associated with the maturity of hybrids. Ear-to-TDM ratio and % DM decreased with delayed maturity of hybrids.

The relationship between GDD accumulated from silking to harvest for each hybrid and % DM at harvest is shown in Figure 13. A total of 538 C GDD is required to obtain the optimum of 33% DM for good quality silage. According to the regression equation in Figure 13, a GDD of about 11.5 C is required to increase the % DM by one unit. During late September the accumulated GDD in one day ranges

Table 17. Photosynthesis and total chlorophyll content of 20 corn hybrids 30 days after emergence at the April 21 planting.

| Hybrid | Photosynthesis | Chlorophyll |
|---|---|---|
| | mg $CO_2/dm^2/hr$ | $mg/dm^2$ |
| Cornell 110 | 51.4 ns | 4.3 ns |
| Cornell 103 | 47.3 | 4.7 |
| Stewart 2501 | 49.1 | 3.7 |
| Seneca 140 | 41.2 | 4.3 |
| Minhybrid 806 | 48.4 | 3.6 |
| Old Fox 905 | 41.7 | 4.4 |
| Funk 5048 | 39.8 | 3.5 |
| Asgrow RX-29 | 46.5 | 3.5 |
| Asgrow RX-35A | 48.9 | 4.1 |
| Dekalb XL-12 | 55.6 | 4.4 |
| Wisc. 335A | 55.7 | 4.4 |
| NK PX-446 | 45.8 | 4.2 |
| Seneca 285 | 41.1 | 3.8 |
| Agway 393S | 44.1 | 3.9 |
| NK PX-32 | 42.5 | 4.2 |
| Dekalb XL-43 | 48.0 | 3.8 |
| Agway 595S | 51.1 | 4.3 |
| Agway 590X | 56.8 | 4.1 |
| Old Fox 1105 | 43.8 | 4.0 |
| Dekalb XL-640 | 45.8 | 4.2 |
| CV, % | 18.0 | 11.9 |

Table 18. Total dry matter (TDM) yield of 20 corn hybrids at two planting dates.

| Hybrid | Planting date April 21 | Planting date May 19 | Average |
|---|---|---|---|
| | metric tons/ha | | |
| Cornell 110 | 14.3 | 15.1 | 14.7 def |
| Cornell 103 | 15.2 | 14.9 | 15.1 def |
| Stewart 2501 | 14.3 | 16.0 | 15.2 def |
| Seneca 140 | 16.3 | 15.5 | 15.9 def |
| Minhybrid 806 | 15.3 | 15.7 | 15.6 cdef |
| Old Fox 905 | 15.2 | 14.9 | 15.1 def |
| Funk 5048 | 15.4 | 14.6 | 15.0 def |
| Asgrow RX-29 | 17.0 | 13.4 | 15.2 def |
| Asgrow RX-35A | 14.5 | 14.0 | 14.3 ef |
| Dekalb XL-12 | 16.5 | 16.0 | 16.3 cde |
| Wisc. 335A | 12.6 | 14.4 | 13.5 f |
| NK PX-446 | 16.5 | 14.5 | 15.5 cdef |
| Seneca 285 | 14.4 | 14.8 | 14.6 def |
| Agway 393S | 16.5 | 17.1 | 16.8 cd |
| NK PX-32 | 20.4 | 18.9 | 19.7 ab |
| Dekalb XL-43 | 16.8 | 18.0 | 17.4 c |
| Agway 595S | 18.9 | 16.9 | 17.9 bc |
| Agway 590X | 17.5 | 16.4 | 17.0 cd |
| Old Fox 1105 | 20.0 | 19.1 | 19.6 ab |
| Dekalb XL-640 | 20.9 | 19.6 | 20.3 a |
| Average | 16.4 A | 16.0 A | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

Table 19. Ear yield of 20 corn hybrids at two planting dates.

| Hybrid | Planting date: April 21 | Planting date: May 19 | Average |
|---|---|---|---|
| | metric tons/ha | | |
| Cornell 110 | 8.4 | 8.9 | 8.7 ns |
| Cornell 103 | 9.9 | 9.0 | 9.5 |
| Stewart 2501 | 9.1 | 9.4 | 9.2 |
| Seneca 140 | 10.6 | 9.0 | 9.8 |
| Minhybrid 806 | 9.4 | 9.6 | 9.5 |
| Old Fox 905 | 9.3 | 8.5 | 8.9 |
| Funk 5048 | 8.2 | 8.0 | 8.1 |
| Asgrow RX-29 | 10.4 | 7.5 | 9.0 |
| Asgrow RX-35A | 8.6 | 8.1 | 8.3 |
| Dekalb XL-12 | 10.2 | 9.0 | 9.6 |
| Wisc. 335A | 7.5 | 7.7 | 7.6 |
| NK PX-446 | 9.5 | 8.2 | 8.9 |
| Seneca 285 | 8.1 | 7.9 | 8.0 |
| Agway 393S | 9.4 | 8.6 | 9.0 |
| NK PX-32 | 10.9 | 8.9 | 9.9 |
| Dekalb XL-43 | 9.4 | 9.0 | 9.2 |
| Agway 595S | 10.9 | 8.9 | 9.9 |
| Agway 590X | 10.3 | 8.6 | 9.5 |
| Old Fox 1105 | 10.7 | 7.9 | 9.3 |
| Dekalb XL-640 | 9.1 | 7.3 | 8.2 |
| Average | 9.5 A | 8.5 B | |

Averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level.

Table 20. Ear-to-TDM ratio of 20 corn hybrids at two planting dates.

| Hybrid | Planting date: April 21 | Planting date: May 19 | Average |
|---|---|---|---|
| | % | | |
| Cornell 110 | 58.7 | 59.1 | 59.0 abc |
| Cornell 103 | 65.5 | 60.4 | 63.0 a |
| Stewart 2501 | 63.3 | 58.5 | 60.9 abc |
| Seneca 140 | 64.6 | 58.1 | 61.4 ab |
| Minhybrid 806 | 60.5 | 61.1 | 60.8 abc |
| Old Fox 905 | 61.2 | 56.9 | 59.1 abc |
| Funk 5048 | 53.4 | 55.3 | 54.4 def |
| Asgrow RX-29 | 61.5 | 55.6 | 58.6 abcd |
| Asgrow RX-35A | 59.1 | 57.8 | 58.5 abcd |
| Dekalb XL-12 | 61.3 | 56.2 | 58.8 abcd |
| Wisc. 335A | 60.1 | 54.0 | 57.1 bcde |
| NK PX-446 | 57.7 | 56.7 | 57.2 bcde |
| Seneca 285 | 56.4 | 53.6 | 55.0 def |
| Agway 393S | 57.2 | 50.3 | 53.8 def |
| NK PX-32 | 53.8 | 47.1 | 50.5 fg |
| Dekalb XL-43 | 56.0 | 49.7 | 52.9 ef |
| Agway 595S | 57.5 | 52.6 | 55.1 def |
| Agway 590X | 58.7 | 52.7 | 55.8 cde |
| Old Fox 1105 | 53.4 | 41.6 | 47.5 g |
| Dekalb XL-640 | 43.8 | 37.4 | 40.6 h |
| Average | 58.2 A | 53.8 A | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

Table 21. Percent dry matter (% DM) of 20 corn hybrids at two planting dates.

| | Planting date | | |
|---|---|---|---|
| Hybrid | April 21 | May 19 | Average |
| Cornell 110 | 39.4 | 36.5 | 38.0 bcd |
| Cornell 103 | 41.1 | 38.6 | 39.9 bc |
| Stewart 2501 | 52.1 | 37.1 | 44.6 a |
| Seneca 140 | 41.7 | 37.9 | 39.9 bc |
| Minhybrid 806 | 46.9 | 37.0 | 42.0 ab |
| Old Fox 905 | 38.3 | 34.0 | 36.3 cdef |
| Funk 5048 | 41.4 | 34.4 | 37.9 cd |
| Asgrow RX-29 | 41.2 | 34.4 | 37.8 cde |
| Asgrow RX-35A | 38.9 | 32.0 | 35.5 def |
| Dekalb XL-12 | 37.1 | 32.1 | 34.6 defg |
| Wisc. 335A | 35.7 | 31.0 | 33.4 efgh |
| NK PX-446 | 36.7 | 29.4 | 33.1 efghi |
| Seneca 285 | 31.6 | 29.2 | 30.4 hij |
| Agway 393S | 34.4 | 30.5 | 32.5 efghi |
| NK PX-32 | 33.1 | 29.1 | 31.2 fghi |
| Dekalb XL-43 | 30.5 | 28.1 | 29.3 ij |
| Agway 595S | 35.2 | 29.0 | 32.1 fghi |
| Agway 590X | 33.6 | 28.3 | 31.0 ghi |
| Old Fox 1105 | 29.7 | 25.1 | 27.5 j |
| Dekalb XL-640 | 27.9 | 25.3 | 26.7 j |
| Average | 37.4 A | 32.0 B | |

Averages of hybrids in a column followed by the same small letter and averages of planting dates in a row followed by the same large letter are not significantly different at the 5% level by DNMRT.

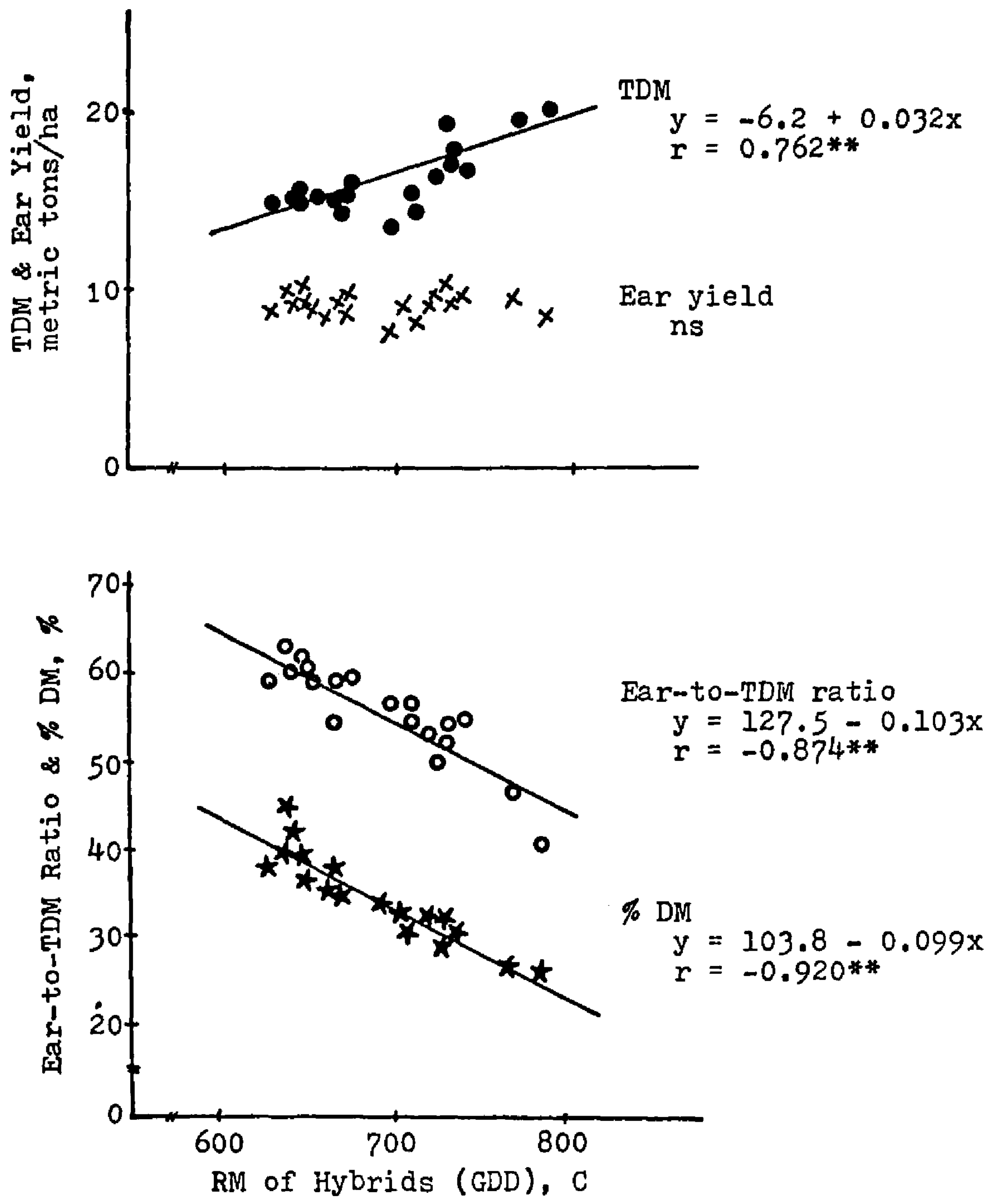



Fig. 12. Relationships between RM and TDM (●), ear yield (×), ear-to-TDM ratio (o), and % DM (✱) of 20 corn hybrids. Each data point represents the average of two planting dates.

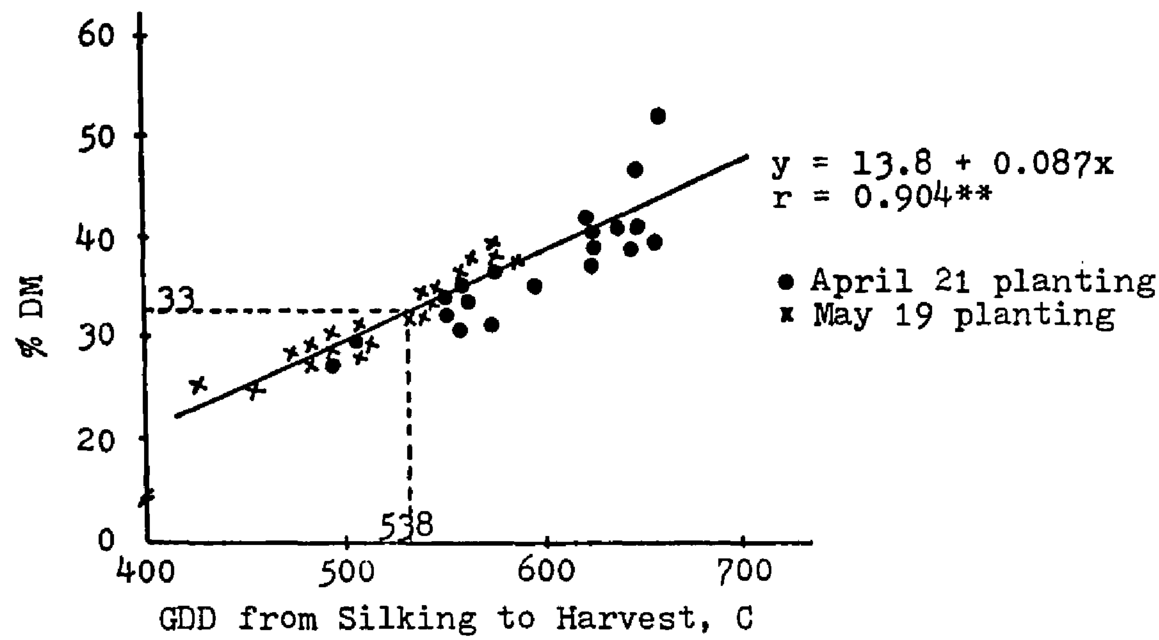



Fig. 13. Relationship between GDD from silking to harvest and % DM of 20 corn hybrids at two planting dates.

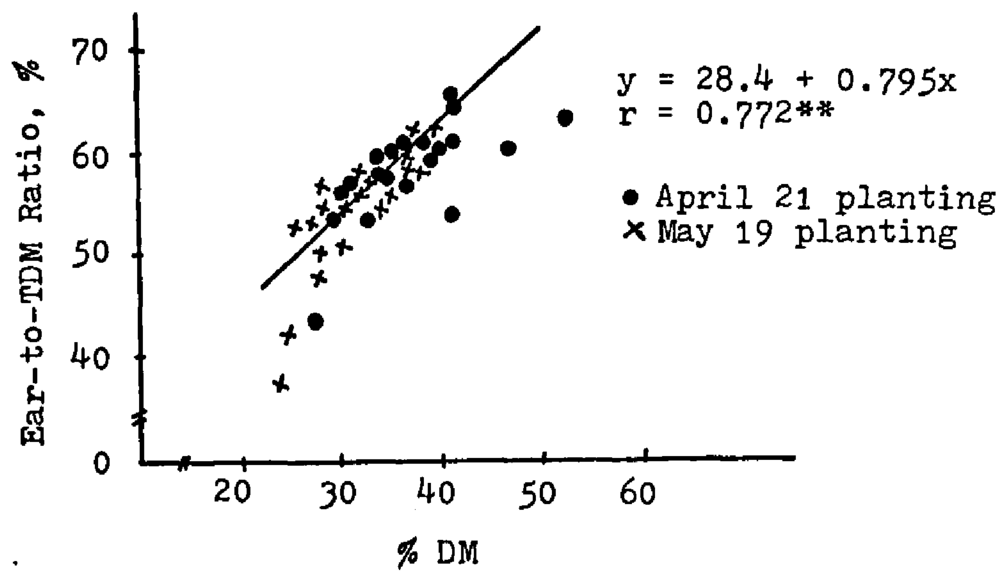



Fig. 14. Relationship between % DM and ear-to-TDM ratio of 20 corn hybrids at two planting dates.

from 3-5 C (Figure 1). Thus, 2-4 days are required to increase the % DM by one unit. The average first fall frost date in Durham, N.H. is September 26. According to the 12-year temperature data corn should silk by July 27 to achieve 33% DM at this location.

The relationship between % DM and ear-to-TDM ratio of each of the 20 corn hybrids is shown in Figure 14. The ear-to-TDM ratio decreased with decreasing % DM of hybrids at a relatively slow rate until approximately 30 % DM, after which the ratio rapidly decreased.

Date of planting did not significantly affect the fall yield of stover or the LAI at the silking stage. Both the stover yield and LAI increased with delayed maturity of 20 corn hybrids (Figures 15 and 16).

Experiment III: Hybrid x Location Interaction

A combined analysis was employed to analyze data from four locations since it was accepted by Cochran's normality test (Bartlett, 1937). The results are shown in Table 22. Since location, hybrid, and their interaction were significant for all characters, hybrids were compared for each specific location. Because the relationship between maturity of hybrids and plant productivity was considered more relevant than the response of individual hybrids at different locations, these data are presented in Figure 17.

Growing conditions in terms of GDD ranged from 1,000-1,110 C in the northernmost location to 1,330 C in

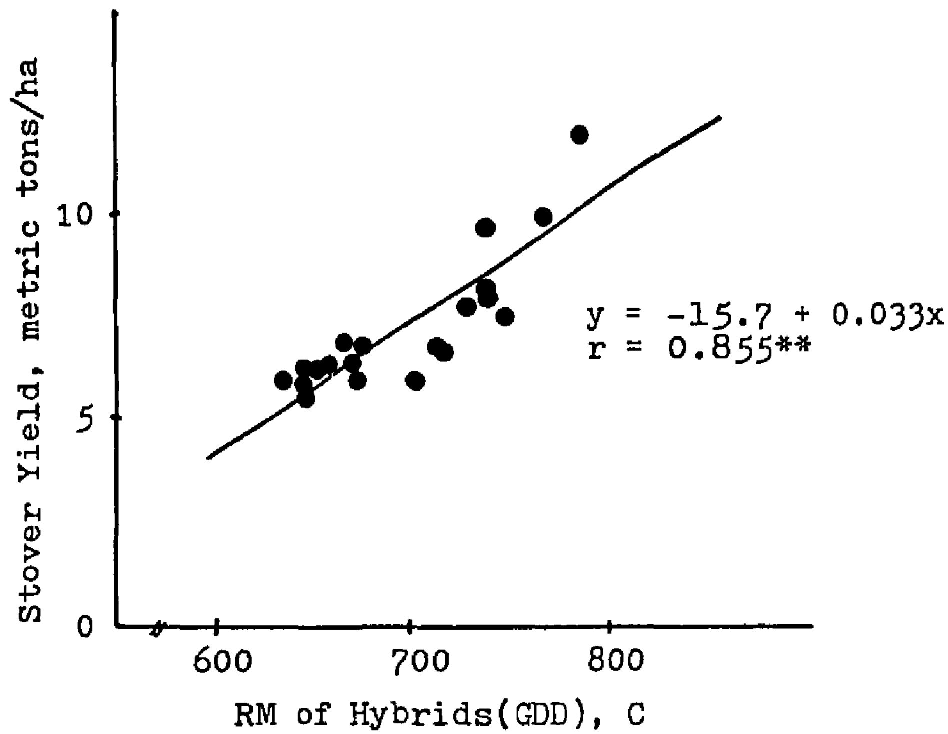



Fig. 15. Relationship between RM of 20 corn hybrids and stover yield. Each data point represents the average of two planting dates.

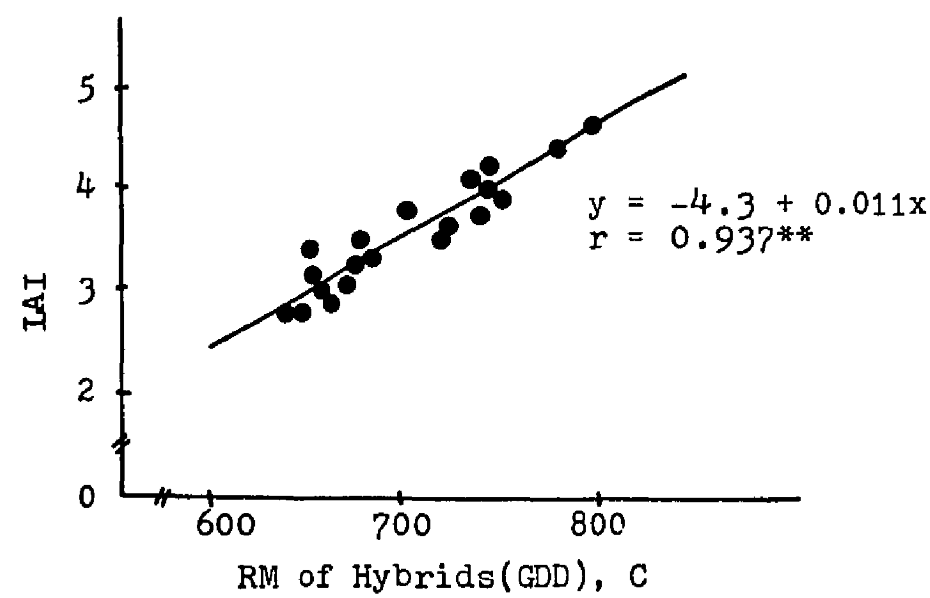



Fig. 16. Relationship between RM of 20 corn hybrids and LAI at the silking stage. Each data point represents the average of two planting dates.

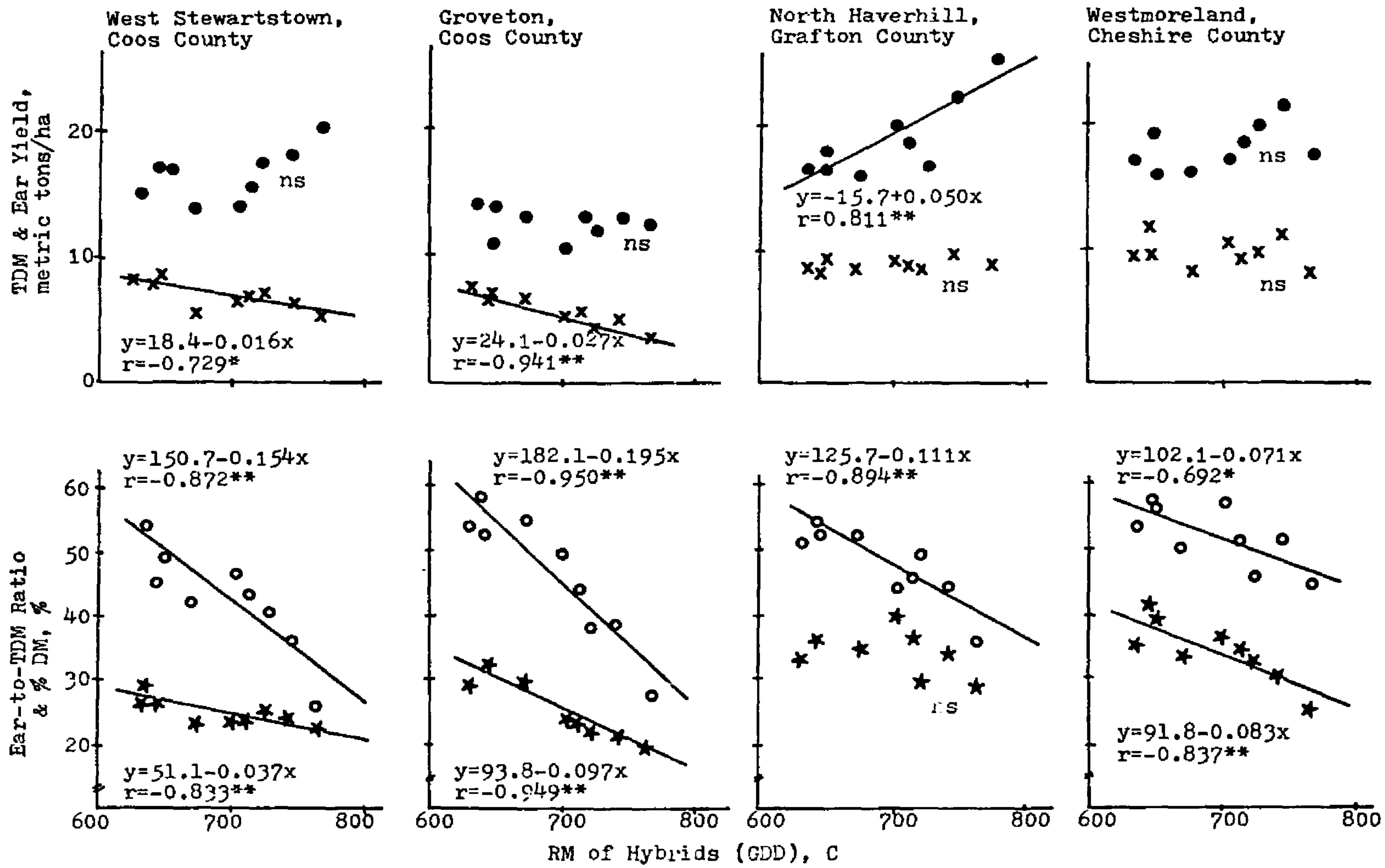



Fig. 17. Relationships between RM and TDM (●), ear yield (x), ear-to-TDM ratio (o), and % DM (★) of 9 corn hybrids grown at four locations.

Table 22. Analysis of variance for TDM, stover yield, ear yield, ear-to-TDM ratio, and % DM of 9 corn hybrids grown at four locations.

| | | Mean squares | | | | |
|---|---|---|---|---|---|---|
| Source | df | TDM yield | Stover yield | Ear yield | Ear-to-TDM ratio | % DM |
| Rep/Loc | 8 | 4.8 | 3.8 | 1.2 | 14.1 | 22.7 |
| Loc, L | 3 | 228.0** | 46.0** | 89.6** | 414.9** | 633.8** |
| Hybrid, H | 8 | 24.5** | 42.8** | 5.9* | 523.6** | 128.5** |
| L x H | 24 | 9.6* | 3.9** | 2.7* | 47.3** | 18.5** |
| Error | 64 | 4.8 | 1.7 | 1.6 | 21.0 | 4.6 |

*, ** Significant at the 5 and 1% levels, respectively.

the most southern area (Figure 1). At the two northern sites, the yield of TDM was not affected by the maturity of hybrids. However, ear yield, ear-to-TDM ratio, and % DM decreased with delayed maturity of the hybrids. At these northern sites, % DM of almost all hybrids was lower than the optimum value of 33% in spite of the relatively late harvest of October 5.

In Grafton county, yield of TDM increased with delayed maturity of the hybrids but no difference occurred in ear yield among hybrids. Ear-to-TDM ratio decreased with delayed maturity of hybrids. Percent DM was not related to maturity of hybrids but values higher than 30% occurred with all hybrids.

In Cheshire county, TDM and ear yield were not related to the RM of hybrids. However, the ear-to-TDM ratio and % DM decreased with delayed maturity of hybrids. The harvest was made on September 23 (one week earlier than in Grafton county) and late hybrids, especially Old Fox 1105, did not show full growth.

# DISCUSSION

## Emergence of Seedlings

At the lowest greenhouse temperature of 15/10 C, the percent emergence of most hybrids was low and differences were observed among hybrids in both emergence and subsequent growth; no similar differences occurred at 20/15 and 26/21 C. This differential response of hybrids in emergence to different temperatures under controlled conditions was previously reported by Cal and Obendorf (1972).

Emergence under the field conditions was more rapid than under the greenhouse conditions, even though the average temperature was lower. Percent stand of all hybrids was higher than 85% in the field except for the June 2 planting (Tables 9 and 15) when soil moisture was low (Figure 5). No differences in percent stand occurred among hybrids even in the very early planting of April 21 except for three hybrids whose percent emergence was also low at all temperature treatments in the greenhouse. Soil temperature during the emergence period following the planting of April 21 averaged 10.3 C (Table 7). However, unlike the controlled greenhouse conditions of 15/10 C, a much higher maximum day temperature as well as progressively higher daily temperatures occurred following planting (Figure 2). Such temperature differences in the field are probably significant in improving both germination and subsequent growth.

Under field conditions, average mean soil temperatures during the emergence period were closely related to days from planting to emergence; "$y = 1/( 3.0 - 825.7/x)$", where "y" is days from planting to emergence and "x" is the average soil temperature in degrees Kelvin. Lindstrom et al. (1976) also found a similar relationship in wheat.

## Early Growth

Under the low temperatures of the April 21 planting, two of the very early hybrids grew best as evidenced by their higher dry weight 30 days after emergence (Table 16). However, as temperature conditions became more favorable for corn growth, as in the May 19 planting, plant dry weight was significantly correlated with the maturity of hybrids (Figure 11). A similar relationship was observed in the June 2 planting in the field (Table 10) and at temperatures of 15/10 and 20/15 C in the greenhouse. Other work has shown an inverse relationship between the rate of early growth and heat unit requirement of hybrids as an index of maturity at 10 and 16 C. In contrast, at near optimum greenhouse temperatures of 26/21 C, the dry weight of an early and a late hybrid was essentially the same four weeks after temperature treatments (Table 6).

In the field, photosynthetic activity measured 30 days after emergence from the April 21 planting was not related to the dry matter accumulated ($r = 0.274$). Such results are not surprising, since it has been found that growth is not well correlated with unit area rates of photosynthesis (Heichel and Musgrave, 1969).

The ultrastructure of chloroplasts differed between two hybrids grown at low air temperatures. Chloroplasts at 15/10 C in the early hybrid, Cornell 110, were normal. At the same temperatures, chloroplasts of the late hybrid, Agway 590X, showed ultrastructural changes: reduced number of granal stacks and stromal lamellae, swelling of peripheral reticulum, alteration of chloroplast shape. Some similar ultrastructural changes were noted in sorghum (Taylor and Craig, 1971). The occurrence of rudimentary grana in the bundle sheath cell chloroplasts and disconnected lamellae in both mesophyll and bundle sheath cell chloroplasts may influence photosynthesis although no literature support currently exists.

The differential reduction in photosynthesis of the two hybrids at 15/10 C compared to 20/15 C may be related to the alteration of chloroplast structure and/or enzyme activity. At 20/15 C, photosynthesis of Agway 590X was higher than that of Cornell 110; 25.1 vs 14.5 mg $CO_2/dm^2/hr$. However, at 15/10 C, no significant differences occurred in photosynthesis between Agway 590X and Cornell 110; 8.9 vs 11.5. When the percent reduction of photosynthesis of each hybrid is considered, at 15/10 C, the photosynthesis of Agway 590X and Cornell 110 was 35.5 and 79.3% of that at 20/15 C, respectively. Therefore, the reduced number of grana stacks and stroma lamellae, and some disconnected lamellae in Agway 590X may affect the function of chloroplasts to fix $CO_2$ and translocate assimilates.

In the field, air temperature in May is frequently lower than 10 C, mainly at night. Under both low temperature and light intensity, changes in chloroplast ultrastructure and chlorophyll photodestruction may not occur (Taylor and Craig, 1971; MacWilliam and Naylor, 1967). However, synthesis of chlorophyll may be retarded by low temperature (Roberts, 1969). Although alteration of chloroplast ultrastructure and photodestruction of chlorophyll may occur under high light intensity and low temperature on certain days, a rapid recovery from this low temperature stress will occur under favorable conditions (Kleins, 1960). Because of this recovery mechanism, a late hybrid like Agway 590X can still be planted early in spite of an alteration of chloroplast structure and reduced photosynthesis under low temperature stress conditions which may result in poorer early growth compared to other more adapted hybrids.

Effect of Hybrid on Yields

The association of high stover yield with delayed maturity of hybrids (Figure 15) agrees with the results of Hanway and Russell (1967).

With ear yield, a significant interaction occurred between hybrids and locations (Table 22). In northern N.H., a decreasing ear yield with delayed maturity of hybrids

(Figure 17) is likely related to a slower rate of growth under cool temperature conditions and a shorter period of time from silking to harvest of the late- compared to early-maturing hybrids. However, in central and southern N.H., no significant relationship occurred between maturity and ear yields of hybrids (Figures 12 and 17). Hanway and Russell (1969) also found no differences in ear yield among hybrids of varying maturity in Iowa.

In northern areas where the temperature decreases rapidly in the fall, early silking of the adapted hybrids results in higher ear yield with smaller LAI or plant size. In southern areas where the growing season is relatively long, the late hybrids which have a large LAI (Figure 16) outyield the early hybrids. In this context, if these same hybrids are planted in an area where the growing season is long enough for maturity of the latest hybrids, ear yield would likely closely relate with maturity of the hybrids although no experimental data are available. Under these conditions, early hybrids would mature before the first frost, while late hybrids would utilize the entire growing season with their greater yield potential. In fact, Stivers et al. (1971) found that "full season hybrids" generally produced higher yields of grain compared to either early or late hybrids.

Total dry matter yields were also significantly influenced by hybrids and locations (Table 22) but responded differently from ear yield (Figures 12 and 17). In northern

N.H., yield of TDM was not related to maturity of hybrids, while in central and southern N.H., TDM increased with delayed maturity of hybrids. As with ear yield, if the same hybrids are planted in cool northern areas, TDM may decrease with delayed maturity of hybrids.

In Cheshire county, plant response with the same hybrids differed from results of central and southern N.H., and is not fully understood. Although the annual accumulation of GDD in Cheshire county is higher than in Durham (Figure 1), the last spring frost for Cheshire county is about one week later and the first fall frost is about one week earlier than for Hanover or Durham (Appendix). Consequently, the late hybrids may not fully develop. Evidence of this is seen in the yield of the latest hybrid, Old Fox 1105, which was significantly lower than the next maturing hybrid (Figure 17).

The ear-to-TDM ratio and % DM decreased with delayed maturity in all locations except for % DM in central N.H. (Figures 12 and 17). Bruetsch and Estes (1976) also used % DM as an index of maturity of silage corn hybrids.

Effect of Planting Date on Yield

Early planting resulted in significantly higher ear yield, ear-to-TDM ratio, and % DM (Tables 12, 19, 20, and 21) except ear yield in Experiment I (Table 1). Although a lower LAI occurred in the early planting (Table 9), improved temperatures and longer day length during the grain formation period may have produced the observed higher grain yield from this April 21 planting compared to the May 19 planting. Similar results were found from different planting dates in Iowa (Pendleton and Egli, 1969). If planted early, the extended length of the grain formation period has special value for the late hybrids which would otherwise be immature at harvest with a normal planting date (Table 13). Therefore, temperature during the grain formation period (Duncan et al., 1966) and length of grain formation period as well as LAI (Eik and Hanway, 1966) are closely related to the grain yield.

Significant differences in TDM yield occurred between plantings when all hybrids were averaged (Tables 12 and 18). However, the increased % DM and ear-to-TDM ratio of an early planting make it feasible to grow late hybrids and achieve higher yields of mature corn. Percent DM warrants special consideration since it is the most reliable index of maturity for silage corn (Daynard and Hunter, 1975). The % DM of Agway 590X was 28.3% when planted on the normal planting date (May 19), but when planted earlier (April 21) % DM was optimized to 33.6% by the time of harvest (Table 20). Estimated yield potential of Agway 590X and Asgrow RX-35A calculated from the equation of Figure 12 was 17.7 and 15.5 metric tons/ha, respectively. Thus, if Agway 590X is planted early, it may produce about 14% more yield compared to Asgrow RX-35A in the normal planting with similar % DM or silage quality. A similar approach could be applied to data from Grafton county where yield responses with maturity of hybrids are quite similar to those observed at the Univ. of New Hampshire Agronomy Research Farm, Madbury, N.H. Conversely, in northern N.H. late hybrids may produce the same TDM as early hybrids but do not mature or develop adequate quality for ensilage due to slow early growth and the short growing season (Figure 17). In this northern area, early planting of short-season hybrids will not affect TDM yields but will increase % DM for improved silage quality. When planted on the normal date in this area, all hybrids were harvested with less than 30% DM of entire plants.

## Plant Population

The lack of differences in TDM between plant populations (62,700 vs 79,700 seeds/ha) in this research indicates that plant population may not be a major consideration in early plantings of silage corn. A wide range of optimum plant populations for silage corn hybrids appears to exist. Other workers reported that the optimum plant population for silage corn was from 69,000-98,000 plants/ha depending on experiments (Hicks and Stucker, 1972; Rutger and Crowder, 1967; Stivers et al., 1971; Cummins and Dobson, 1973).

## Determination of Planting Date

When corn is planted several days before the last average frost date in spring, it takes about 11 days for emergence (Table 7). Thus, if corn is planted 7-10 days before the last frost date, it will emerge about 1-4 days after the average last frost date. In this research, the earliest planting of April 21 was made 27 days before the last frost date of May 18, but no specific problems were observed; no frost occurred after April 21 in 1976.

The earliest possible planting dates without appreciable risk of frost in Berlin, Hanover, Durham, and Keene would be May 14, May 9, May 8, and May 13, respectively, based on the data of Kolega and Palmer (1963). Since the temperature usually increases rapidly after this last spring frost date (Appendix), seedling growth will benefit from the early planting. While planting earlier than the above dates may be possible due to the yearly variation in climate, limited benefits will likely occur due to low temperatures.

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# APPENDIX

Growing degree days (C) weekly summaries in four locations in New Hampshire (Kolega and Palmer, 1961).

| Period | Berlin | Hanover | Durham | Keene |
|---|---|---|---|---|
| April 26 - May 2 | 6.2 | 10.7 | 10.6 | 11.7 |
| May 3 - May 9 | 12.6 | 17.5 | 19.3 | 20.1 |
| May 10 - May 16 | 11.9 | 16.6 | 17.9 | 19.8 |
| May 17 - May 23 | 18.2 | 25.0 | 26.7 | 28.6 |
| May 24 - May 30 | 30.5 | 35.7 | 37.9 | 38.5 |
| May 31 - June 6 | 35.3 | 43.2 | 45.9 | 45.2 |
| June 7 - June 13 | 40.4 | 49.8 | 51.9 | 52.0 |
| June 14 - June 20 | 46.2 | 56.5 | 56.5 | 57.7 |
| June 21 - June 27 | 53.4 | 64.6 | 67.7 | 67.2 |
| June 28 - July 4 | 59.5 | 69.4 | 74.1 | 70.5 |
| July 5 - July 11 | 64.9 | 75.6 | 79.1 | 76.9 |
| July 12 - July 18 | 63.5 | 74.4 | 79.1 | 76.3 |
| July 19 - July 25 | 67.6 | 77.1 | 81.3 | 79.7 |
| July 26 - Aug. 1 | 66.1 | 77.3 | 81.4 | 80.3 |
| Aug. 2 - Aug. 8 | 57.7 | 69.3 | 74.5 | 71.1 |
| Aug. 9 - Aug. 15 | 60.5 | 72.3 | 76.9 | 74.5 |
| Aug. 17 - Aug. 22 | 54.8 | 65.4 | 70.5 | 67.0 |
| Aug. 23 - Aug. 29 | 49.5 | 60.3 | 66.2 | 61.3 |
| Aug. 30 - Sept. 5 | 44.8 | 57.3 | 62.1 | 59.6 |
| Sept. 6 - Sept. 12 | 32.7 | 45.0 | 50.3 | 47.5 |
| Sept. 13 - Sept. 19 | 27.6 | 38.8 | 43.8 | 41.7 |
| Sept. 20 - Sept. 26 | 21.8 | 28.1 | 34.9 | 31.7 |
| Sept. 27 - Oct. 3 | 13.1 | 17.9 | 24.5 | 22.0 |
| Total | 938.8 | 1,137.1 | 1,233.1 | 1,200.6 |
| Last spring frost | 5/24 | 5/19 | 5/18 | 5/23 |
| First fall frost | 9/14 | 9/26 | 9/26 | 9/20 |
| Growing degree days during the frost free period | 855 | 1,074 | 1,161 | 1,067 |

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